Human Psychology

Howard C. Warren

HUMAN PSYCHOLOGY

BY

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HUMAN PSYCHOLOGY

CHAPTER I

THE SCIENCE OF PSYCHOLOGY

Preliminary Definitions. — Psychology is the scientific investigation of mental life. Mental life comprises the events which occur in the active give-and-take relations between organisms and their environment.

These are not intended as final definitions; they indicate in a preliminary way the general field which psychology covers. First of all we must be sure that we understand the meaning of the principal terms in these statements. What is meant by scientific investigation, or *science?* What is an *organism,* and what are the characteristic features of *organization?* These notions must be made clear before we can see just what is included within the field which we are to investigate.

Science. — It may seem unnecessary to explain what is meant by scientific investigation. But while most of us are familiar in a general way with the 'sciences of nature,' we do not always realize that the same facts which form the subject-matter of science may also be treated in other ways and fall outside the province of science. For example, the same material may be used as an *instrument* for other purposes, or it may be studied *historically.*

When we take up the study of French, for instance, we may propose to become familiar with the structure of the language and the general principles or laws of inflection, grammar, and the like. This would be a *scientific* study of the language. On the other hand, we may take no interest in this aspect, but may wish rather to attain a practical mastery of French in order to speak it and to read French literature. In this case

we are not concerned with the science of French but with French as an *instrument* for acquiring information of other sorts. Finally, we may be interested in neither of these aspects of French, but in the *historical development* of the language. In all three cases the material we deal with is largely the same; but the mode of procedure and the facts brought out are quite different. The same subject-matter may be treated either (1) scientifically, or (2) practically, or (3) historically. These three view-points lead in any branch to Science, Art, and Genetics.

The distinction just noticed is of greater importance in psychology than in most branches, because psychology deals with phenomena of our intimate personal life, and its processes are used to obtain information of every sort. Mental facts, like the French language used in our illustration, may be studied in at least three different ways:

(1) As a *science.* We may seek to discover the principles or laws of mental life and activity, such as the modes of habit formation, the laws of association, thinking, etc.

(2) As an *instrument,* to obtain information of other sorts. If we wish to understand the nature of the world itself, including matter as well as living creatures, we proceed by means of 'rational thinking'; and rational thinking, or logic, is a mental process. But when we use logical principles in order to understand the universe we are not studying mental facts as a science, but only as an instrument for philosophical research. Or again, we may use psychological principles in order to classify human beings on a scale of higher and lower intelligence. Here again we are not studying the science of mental phenomena — we are merely using the principles of mental life as an instrument in investigations of another sort. This study is known as *applied* psychology.

(3) As an *historical growth* or development. Mental states and processes are subject to change and growth. They differ in the child and the human adult; they exhibit various forms

in different animal species. This historical study constitutes a department of study in itself, quite different from the study of the principles of mental activity in any one of the stages or species. It is called *genetic* psychology.

When we speak of the *science of psychology* it should be made perfectly clear whether we are concerned with the *static* view of mental operations as they appear in some definite form of being, or with the *application* of the principles of mental life to some other sphere, or with the *genetic development* of mental phenomena. In this book our interest centers mainly upon the static view; we are to investigate the phenomena which constitute the mental life of adult human beings.

Classification of Science. — It will help us to understand the field of psychology if we consider its relation to the other branches which are ordinarily grouped under the generic term *science*. Science means the discovery and systematic formulation of general truths of nature. The division of science into branches is more or less a matter of convenience. Nature is a single interworking system of things and events, and hence in a way all science is one. But for convenience of study we group together those phenomena which are similar in character, and we investigate them apart from the rest. Any such group is called 'a science.' For example, the properties and combinations of elements in a cell are studied in the science of *chemistry*, the play of forces in the science of *physics*, the special activities of cells in the science of *physiology*. These events usually occur at the same time and concern the same objects; but the investigator or student examines one set or class, assuming or passing over the others for the time being.

It should be emphasized also that science as such is not concerned with individual facts or events. Each event is considered as representing any number of similar events, and it is especially the *interworking* of events that interests the scientist. The observation of nature in all its phases during many centuries has shown us that nature *acts uniformly* —

that given the same conditions, the same results follow. The doctrine of the 'uniformity of nature' enables us to experiment with individual things and to apply the results of these particular observations to all similar things by means of generalizations, or 'laws.'

The most fundamental division of science is into *abstract* and *concrete*. Abstract science investigates the relations which hold equally well for every kind of specific facts. The abstract sciences include *mathematics* in all its branches and *logic*. Quantitative and numerical relations apply alike to atoms, masses, forces, and living creatures. What the savage or the child discovers by counting his fingers and by adding, subtracting, and grouping them in various ways, may be applied on a larger scale to the study of the stars and to tables of human mortality — in fact to all phenomena. The intelligent man forms habits of mathematical association and uses them in connection with every event of life. These habits are modes of reasoning, and when they are developed into an organized system they become a branch of science — or a group of such branches. These branches form the *abstract sciences*, or, as they are sometimes called, the *mathematical* sciences. They may also be called the *general* sciences, since they hold for all classes of natural phenomena.

The concrete sciences deal with phenomena which belong to *special phases* of nature. They are also often called *special sciences* or *empirical sciences*, which points to the fact that the truths of nature in each specific field are discovered by observing the actual course of events in that field, and not by taking the truths discovered in one sphere and applying them to another without question.

Formerly scientists thought it proper to carry over generalizations from one field to another in this way. It was assumed that the planets revolved in circles on account of the geometrical simplicity of the circle. Even Newton assumed that there must be seven primary colors corresponding to the seven

tones of the musical scale. We find many such instances where early science carried over generalizations from one field to another instead of observing the actual course of events. This is called the *apriori* or *rational* method of investigation. At present it has been almost wholly abandoned for the *empirical* method in each of the special fields of science. The laws of abstract science are still carried over to the various concrete sciences; but this is because they have been found by repeated observation to apply universally.

The fundamental concrete sciences are *chemistry* and *physics*. Chemistry deals with the relations between specific material units; physics deals with the general relations between bodies in space and time. At present it is not clear which of these two branches is the more fundamental. Probably they are coördinate phases of nature, a fact which is expressed in the phrase " physicochemical relations."

Biology is another special branch of science, but less fundamental than physics or chemistry. It treats of phenomena which appear only in certain special groups of physicochemical units called organisms. Coördinate with biology are the branches known as *astronomy* and *geology*. All three of these branches deal with 'local' phases of nature which appear on the earth or in the universe about us; they are less general than physics and chemistry. Biology is divided for convenience into a number of branches, such as zoölogy and botany, which need not be discussed here. A more important subdivision of biology is into the three sciences of *morphology*, *physiology*, and *psychology*. Morphology deals with the structure and arrangement of the various parts and organs of living creatures; physiology deals with the internal processes of organisms; psychology with their relations to their surroundings.

A further group of sciences deal with the relations between separate organisms. These are called the *social sciences*. They are less fundamental than biology. The science of *sociology* treats of the general interaction among organisms

of the same species. Human sociology is the most highly developed of these branches, because the human species displays far greater mutual interaction among its members than any other kind of organism. But other species, such as ants and bees, may be studied from the same standpoint. A branch closely related to this is *social psychology*, which examines psychological data so far as they are modified or affected by the social grouping of individuals. Other social branches are *economics*, *ethics*, *jurisprudence*, etc. [Table I.]

TABLE I. — CLASSIFICATION OF SCIENCE

		Branches		*Levels*
1. Abstract (General):	*a*	Logic		I
	b	Mathematics		
2. Concrete (Special):	*a*	Physics Chemistry		II
	b	Astronomy Geology Biology	i Morphology ii Physiology iii Psychology	III
	c	Social Science	i Sociology ii Social Psychology iii Ethics, etc.	IV

Organisms and Organization. — According to this conception of the relation of the sciences, psychology is regarded as a branch of biology, the science which studies certain sorts of units called organisms or living beings.

Plants and animals taken together form one important natural division of the material world. In spite of striking differences in size, shape, and modes of activity, all living things have certain characteristics in common and differ fundamentally from other forms of matter. The words *living* and *lifeless* bring out this distinction. Living creatures are called *organisms*, and lifeless matter is called *inorganic*. What do these terms mean?

Life is often called a force; but this does not help the explana-

tion unless we can determine how this force acts and what it accomplishes.

Animals and plants are very complex aggregations of matter. They consist of several differentiated organs and usually of many segments or members. These parts coöperate in the activities of the creature. *Organization* is the term used to denote the peculiar structural and functional[1] relation of parts which exists in all animals and plants; it means (1) that the parts of a living thing are capable of interaction, and (2) that this capacity persists despite growth and changes of substance. *Life* means that the parts (the organs and members) of an organism act in this coöperative way.

The structure and activities of organisms will be examined later. But it may be stated here that the specific forms of activity called 'organic' are those concerned with the continuance of the creature's individual existence or with the perpetuation of the species. Now the prolongation of existence involves two different sorts of process: (1) internal maintenance and growth, and (2) preservation from external destroying agencies. Thus the activities of organisms may be divided into two classes, which we shall call respectively growth processes or *vitality*, and mental processes or *mentality*.

(1) *Vitality* in the broadest sense expresses the fact that an organism not only is able to restore its losses and repair its injuries, but that during its earlier life it can become larger and more differentiated and in later life can reproduce. (2) *Mentality* is a term used to express a certain give-and-take relationship which exists between an organism and the world about. These two characteristics are due to the special make-up of organized living creatures.

Vital Life and Mental Life. — The various activities which

[1] The term *structure* denotes the composition of a thing and the spatial relations between its parts. *Function* and *process* denote the manner in which the thing acts and its parts interact.

make up the vital functions of growth and maintenance constitute the creature's biological or vital life. We are only indirectly concerned with them here. The object of study in this book is the relations of give and take between organisms and their environment. The facts which arise from these relations are the data of psychology.

If we examine a number of representative organisms, both plant and animal, we observe a very marked difference between their relations to the world about them and the relations of 'inert' matter to its surroundings. An organism is not merely affected by external forces, but on account of its systematic organization it is able to *control* these forces to a greater or lesser extent. It receives impressions from the outer world, and acts accordingly. This characteristic interaction, through stimulation, adjustment, and response, is called *mentality*, and the various activities involved in the process make up the creature's *mental life.*[1]

Among plants interaction with the environment is not often apparent; but sometimes it is unmistakable. The sun-flower, which turns toward the sun and follows its course from east to west, is an instance of stimulation and response. So is the sensitive plant, whose leaves close when they are touched.

Animals exhibit this characteristic to a very marked degree. Their power of locomotion accentuates the response. The lowest species (amœba and other protozoa) respond to stimulation by light, heat, and chemical action on their external covering, and to mechanical contact or pressure. Sometimes the response is positive — that is, *toward* the source of stimulation; in other cases it is negative, that is, *away from* the source.

[1] Many terms, such as *mentality, impulse, stimulation, sensation, contrast, attitude*, are used in a precise, technical way by psychologists. Their meaning is often much narrower or much broader than in popular language. The reader should be careful to 'think' them correctly, according to the definitions given in the text.

Among higher species of animals we find much more complicated types of response. When a partridge sees a hunter approaching her nest she trails off " in an effort to draw him away from her young." This is a negative response to the visual impression of the man's appearance. When a dog sees a rabbit he sets out in pursuit — a positive response which finds expression in violent movements of all the bodily members. In complex activities like these the response usually involves coöperation of many different muscles.

Self-observation; Consciousness. — In man, the highest animal species, we find the greatest complexity of activity. This of itself would give special importance to the study of human psychology. But in addition there is a special circumstance which broadens the sphere of study. Scientific observers belong to the human species. The psychologist can not merely observe the responses of human beings and of animals generally, but he can study his own relations to the environment through *self-observation.*

If we examine our own mental life, we find that the effect of stimulation by outside forces is something different from what we observe in others. When we are affected by a loud sound or a brilliant color, we observe the phenomena in a different way from that in which we observe these forces affecting the ears or eyes of another human being. More than this, we can picture the appearance of a friend when he is miles away; and sometimes we form a tolerably accurate idea of a coming event long before it happens. There is nothing like this in our observations of what animals and other men are doing. Your friend's memories are observed by you only indirectly — you listen to his verbal description of them, or you infer them to be present by the way he acts. Your *own* memories are a direct and immediate part of your life.

The experiences which we observe in ourselves either form a *new set of occurrences* to be examined in connection with the study of mental life; or else they are *another way of looking*

at the same set of facts which we observe in others. The latter hypothesis seems more probable.[1] However, the question of interpretation is far less important than the facts themselves. The phenomena of memory, imagination, perception, and the like, which we notice in self-observation, are grouped together under one general term, *conscious phenomena.*

Consciousness and *conscious* are terms used to characterize the phenomena which occur in an individual's own experience, so far as these differ from what another individual would note in observing him.[2] For instance, when my gaze falls on the old engraving of *Lincoln and his Cabinet* I see the figures grouped together. I recall certain incidents of Lincoln's life and the Civil War. I have an indistinct feeling of attraction and admiration. Another person watching *me* (not the picture) would get practically nothing of all this. Possibly if he could examine my brain with some fine instrument yet to be devised, he would be able to trace out certain chemical and molecular changes corresponding to each detail of my conscious experience. Consciousness denotes the fact that the experience is *personal to me* (' subjective '), and it includes any other distinguishing features of the experience which are apparent to me and not to a second person.

Behavior and Conscious Experience. — The two ways of observing the relation between organism and environment in man bring out quite different sets of facts. When we study the influence of the environment upon some other person than ourselves, the effect of stimulation is observed as a response, which takes the form of some characteristic movement. At a shout, he turns his head and speaks. Seated at a table he picks up his knife and fork and conveys food to his mouth. Passing a shop window he walks up, stops, and casts

[1] See Appendix, "Subjective and Objective Phenomena," p. 413.

[2] The term *conscious,* as here defined, is much narrower than the term *mental.* There are many phenomena in mental life which are not open to self-observation, and are consequently not characterized as conscious phenomena.

his eyes over the articles displayed. All these obvious movements, together with many minute muscular adjustments and secretion by the glands, are effects of the influence of the environment on the man; they constitute his response to stimulation. These motor phenomena, taken together, are called *behavior*.

A man's (or any animal's) behavior includes the various ways in which he acts upon the environment as a result of the environment acting upon him. But the word 'act' is used here in a very specific way. If a violent gust of wind strikes a man suddenly and blows him down, his movement in falling is not behavior, nor is the dent he makes in the ground a response — he is not acting upon the environment in an *organic manner*. But if he is able to brace himself against the wind and avoids falling, or if he puts out his hands to break the fall, these movements are instances of behavior; the external force in such cases affects him not merely physically but also organically — he responds *as an organism* to the stimulation. It is this activity that goes under the name of behavior.

In psychology, then, we do not study every effect of the environment upon the creature, nor every effect produced by the creature on the environment, but only the behavior phenomena — those movements and changes in which the creature is acted upon and responds as an organism.[1]

The second mode of studying mental life is through self-observation (commonly called *introspection*), which examines the phenomena of *conscious experience*. Consciousness phenomena are the effects of the environment upon the creature as they appear to the creature himself.

At first glance it might seem as if the facts of conscious experience were nothing more than the facts which we study in physics and chemistry. When we look at a friend's face, we observe an irregular surface broken up into patches of different

[1] The characteristics of the specific type of activity included under behavior are treated in chapters vi and vii.

colors and shading; these configurations are called the eyes, nose, mouth, cheeks, hair, etc. The human features as we see them are particles of matter reflecting light. The molecular composition of the human body, the grouping of the different cells in space, the reflection of light — all such phenomena are data which properly belong to physics and chemistry and concerning which these sciences have formulated general laws and principles.

But when we study them as effects upon ourselves we are dealing with an entirely different set of relations and principles. When we look at a human face certain features stand out prominent, while others are barely noticed or escape observation altogether. The eyes may be the chief object of attention. The color of the hair may be noticed casually as part of the total impression; a mole on the cheek may remain unnoticed; and so of other features. In a word, the face impresses us *as a whole*, and certain features are *vivid* items of our experience, while other items form a background or *fringe* of fainter impressions. That is, the facts of perception (as this type of experience is called) stand in quite different relations to one another from the physical facts which stimulate us through the eye and other organs. The prominence of certain features in the human face is not always due to the intensity of illumination, nor in most cases is the obscurity of other features due to their actual lack of physical intensity. The difference depends rather upon the internal organization of the perceiving creature. Still more do our 'memory images' and our feelings of pleasure, annoyance, hope, and desire differ from the physical characteristics of the objects which incite them.

The *facts* of conscious experience form a different line of study from the physical facts of the environment, and the *processes* of conscious experience are quite different from physical and chemical processes. These subjective facts and processes form an important part of human psychology and their

study has yielded results far in advance of those obtained by the behavior method.[1]

Definition of Psychology. — We are now in position to define our field of study more precisely. *Psychology is the science which deals with the mutual interrelation between an organism and its environment.*[2] The phenomena (occurrences) which result from these interactions constitute the *mental life* of organisms, and the characteristic arrangement of structures and coöperation of processes which affords this special type of interaction is called *mental organization.* Mental life is distinguished from the vital or ‘growth’ life of organisms. Vital life includes the processes of maintenance, reproduction, and the like. These form the subject matter of physiology. Only one variety of physiological activity — that of the nerves and their terminals — seems at all closely connected with human psychology.

Psychology includes the study of mental life in all kinds of organisms. In this book we shall deal with only part of the field. Our study is limited to the mental life of *man;* the lower species will be examined only incidentally. The reason for this limitation is a practical one. The study of human mental life has made considerably more headway than that of any lower species, and the human type of experience proves to be so far in advance of other types that they can scarcely be treated together. Moreover, human mental life can be studied by self-observation, as well as by observation of others. The former method is not practicable in animal psychology.

Chief Branches of Psychology. — The divisions of psychology, like those of science in general, are somewhat artificial. Nature is more or less a unit, and when we parcel out its facts into separate fields it is rather for convenience of study than to indicate real barriers between different sorts of natural

[1] They are treated in chapters viii to xviii.

[2] The environment includes all external forces and relations which affect the organism — social forces and values as well as physical.

phenomena. In psychology the sharpest dividing line is between *genetic* (dynamic) and *descriptive* (static) psychology.

1. Genetic Psychology is the study of the gradual development of mental life. There are two branches of genetic psychology, one dealing with the mental growth of individuals, the other with mental progress from species to species. If we compare a child with an adult we notice at once the difference in their mental processes. A child of six months cannot dress himself, open a door, use knife and fork, nor perform any of the acts common to civilized life which serve to protect one from external dangers or promote one's general welfare. The growth of mentality in each human individual is gradual. The scientific study of individual mental growth is called *ontogenetic psychology*.

If in the same way we compare human mentality with that of lower animals we find corresponding differences and grades of progress. Formerly it was supposed that each species of animal had a peculiar, specific type of mind, differing from that of all other species. Now that the evolution of species is generally recognized, these different types of mental life are seen to be merely different levels or stages of growth. The science of *phylogenetic psychology* studies the growth or evolution of the various mental processes through the chain of animal species, from protozoa to man.

Genetic psychology includes both of these branches. They may be investigated separately or together. In the present study we shall not take up either of them directly; but the meaning of certain mental facts is plainer if we bear in mind that mental life is a gradual development and that the mental processes found in man are outgrowths of simpler processes which may be observed in subhuman creatures and in children.

2. Descriptive Psychology, the other main branch of psychology, is the study of mental life as it actually *exists* in a species, without special reference to the way in which it has *come to be*. For example, we may examine the nature of hu-

man speech without considering its growth in the child or the race. We may investigate such processes as hearing, imagining, thinking, as they actually exist in man without regard to their origin and growth.

Descriptive psychology is the subject matter of this book. It is difficult to treat the finished product without touching from time to time on its history, but there is no reason why we should avoid this problem. Wherever light is thrown upon the nature of complex mental phenomena by a study of their history, the results of genetic investigation will be taken into account. They form an essential part of the analysis.

Another plan of classification cuts across these lines. We may divide psychology according to our *method of study*. On this basis we distinguish between *behavior* psychology and *self-observation* (or introspective) psychology. Most studies of subhuman psychology employ only the behavior method. The older text-books on human psychology are based very largely on self-observation. But the two methods are closely bound together, and psychologists have begun to realize that each supplements the other. Both methods are needed if we are to obtain a complete understanding of mental life.

For practical purposes the field of study is usually divided into smaller sections. There are text-books and treatises which deal with each of the following:

Human (adult) psychology
Child psychology
Animal (or comparative) psychology
Abnormal psychology
Physiological psychology
Experimental (or laboratory) psychology
Social psychology

The first three have already been explained. *Abnormal* psychology treats of the mental life of individuals whose nervous system is diseased or imperfectly developed. *Physiological* psychology makes a special study of the nervous system

and its operations, in connection with the sensations and other mental phenomena that accompany these operations. *Experimental* or *laboratory* psychology investigates mental phenomena under precise conditions, usually artificially arranged, with the aim of obtaining exact quantitative measurement and clear qualitative determinations. *Social* psychology studies the mental phenomena that occur through the mental interaction of individuals in the community.

In addition there are numerous special branches of psychology such as *psychophysics*, a department of experimental psychology which deals with the relation of stimulus to sensation or perception; *race* psychology, which examines the mental differences between the various human races; and *religious* psychology, which investigates the nature of religious experiences. Any topic which is important enough to receive separate treatment may be regarded as a branch of the science. But this list includes all the chief divisions of psychology.

Collateral Reading:

James, W., Psychology — Briefer Course, ch. 1.
Titchener, E. B., Text-Book of Psychology, ch. 1.
Angell, J. R., Psychology, ch. 1.
Höffding, H., Outlines of Psychology (trans.), ch. 1.
Calkins, M. W., First Book in Psychology, ch. 1.
Yerkes, R. M., Introduction to Psychology, Part I, Part V.
Watson, J. B., Behavior, ch. 1.
Pillsbury, W. B., Fundamentals of Psychology, ch. 1.
Breese, B. B., Psychology, ch. 1.
Calkins, M. W., Introduction to Psychology, ch. 28.
Thomson, J. A., Introduction to Science, ch. 4.
Holmes, S. J., Evolution of Animal Intelligence, ch. 1.
Morgan, C. L., Introduction to Comparative Psychology, ch. 3.
Kirkpatrick, E. A., Genetic Psychology, ch. 1.

Practical Exercises: [1]

Compare your *conscious experience* and *behavior* in copying a sentence.

Draw up a scheme of the sciences and their relations as they appear to you.

Observe the behavior of some young child; describe any immaturity of mental development; e.g., in handwriting, grammar, table habits, self-control, reasoning.

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[1] Directions for performing these exercises are given on p. 447.

CHAPTER II

THE ORGANISM

Vital Organization. — Since psychology is one of the sciences which deal with living organisms, we shall first of all examine the nature of these beings. To understand the constitution of living creatures we must start from the fundamental facts of chemistry. All matter is made up of some 83 different *elements*. Two or more separate particles or *atoms* of these elements combine to form *molecules*. A molecule may consist of atoms of the same sort or of different sorts. If a molecule contains atoms of different kinds it is called a chemical *compound*. Water is a compound; its molecules contain two atoms of hydrogen and one of oxygen; this is expressed in the formula H_2O.

The chemistry of organisms exhibits several distinctive features.

(*a*) The molecules which compose the bodies of living creatures are generally more *complex* than the molecules of 'inorganic' substances which occur under natural conditions. The fundamental element in all organic compounds is carbon. Carbon atoms combine with atoms of oxygen, hydrogen, and nitrogen, and in a lesser degree with atoms of several other sorts,[1] to form organic molecules.

(*b*) Organic molecules are very *large;* that is, they contain a great number of atoms — far greater than is usual in inorganic compounds. For instance the chemical formula for albumen is given as $C_{450}H_{720}N_{116}S_6O_{140}$; that is, 450 atoms of carbon, 720 of hydrogen, etc.[2] In this and other organic substances there are over 1000 atoms in each single molecule.

[1] Traces of sodium, potassium, phosphorus, sulphur, calcium, magnesium, iron, chlorine, etc., are found in some of these molecules.

[2] Goodchild and Tweney, Technol. and Scient. Dic., 1906.

The organic compounds which comprise the body of living creatures are known under the name of *protoplasm*.

(*c*) Another important characteristic of organic compounds is their *instability*. In the living organism the protoplasm is peculiarly subject to changes of constitution. Its molecules are constantly taking in atoms of one sort and releasing those of another, or regrouping the atoms in different ways. This

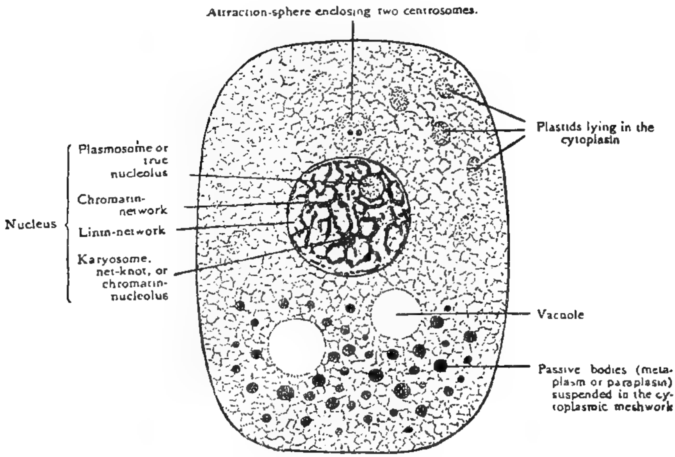

Fig. 1. — The Cell and its Parts

Diagram of an animal cell. The basis consists of a meshwork containing numerous minute granules (microsomes) and traversing a transparent ground-substance. [From Wilson.]

characteristic is of special importance in connection with the relation of the organism to its environment.

(*d*) Molecules of protoplasm combine to form *cells*. [Fig. 1.] A cell consists of a large number of molecules, usually of many sorts. The molecules in a cell are united together somewhat like glue or paste. They hang together firmly, but the whole group can readily alter its shape; substances of this sort, whether organic or inorganic, are called *colloids*.

The cell is the unit of organization in living creatures. There

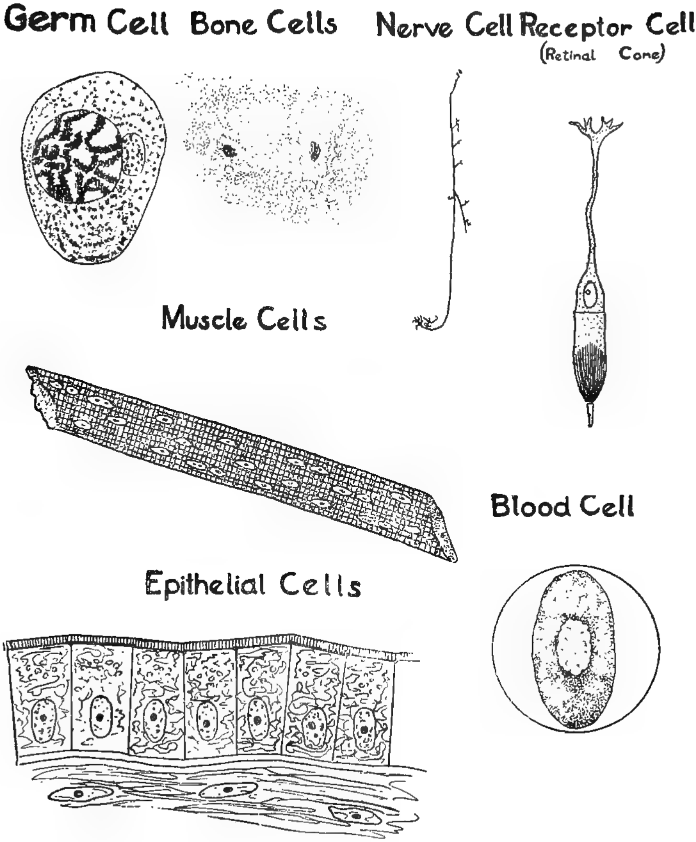

FIG. 2. — TYPES OF CELLS

Some of the commoner cells which make up the organism. [Drawn from preparations and charts; nerve cell from Thorndike.]

are many different types of cell in the human body — germs cells, bone cells, blood cells, epithelial cells, tendon cells, muscle cells, nerve cells, and others. [Fig. 2.] These types differ considerably in their constitution, but all agree in at least two fundamental characteristics: (1) The cell is capable

of *maintaining* itself by ingesting material from without and casting off its own waste products. (2) It is capable under certain conditions of subdividing and thereby *reproducing* new cells.

(1) The first of these characters involves a two-fold process known as *metabolism*. When a cell gathers in new material from the environment and builds up fresh compounds, the process is known as *anabolism*. When it becomes active and its compounds are torn apart and waste material is thrown off, the process is known as *katabolism*. The two processes of anabolism and katabolism are going on constantly in the organism — now one, now the other; often the two are taking place at the same time in neighboring parts of the organism or even in the same cell. This two-fold process of tearing down and renewing organic substance results in maintaining the cell and (on a larger scale) the organism. Katabolism is accompanied by activity and discharge of energy, while anabolism replenishes the energy of the cells and stores it up for future use. Thus metabolism maintains the activity of organic life as well as the constituent matter of the organism.

(2) The second property of the cell is known as *mitosis*, or division. Under certain conditions, by means of a complicated process, a cell subdivides into two complete cells, which may or may not be similar to each other. In the case of germ cells this subdivision marks the beginning of a new and independent organism. Both of the resulting cells henceforth maintain a separate existence. In other types of mitosis the multiplying process continues but the resulting cells remain grouped together, forming a multicellular creature.

If the resulting cells are similar they may remain very closely bound together, forming a bone, a muscle, a skin surface, etc. When such an organ or structure is once formed, if the subdivision of cells continues the organ gradually increases in size but preserves the same general shape. This is illustrated by the growth of the bones in childhood. Mitosis also

generates new cells to replace those which are destroyed or removed by the accidents of life. In addition to repairing the ordinary wear and tear of skin, nails, and other tissues, this effect is seen in the wide-spread renewal of substance lost through a wound. In every case the biological result of mitosis is the same — the production of new cells.

In the lowest plants and animals the organism or creature consists of a single cell, which in coöperation with the environment performs all the various processes involved in maintenance and reproduction. These single-celled organisms are known as protophyta (plants) and protozoa (animals). In higher species of plants and animals the individual consists of a large number of specialized cells grouped together so as to form a unitary organism. These complex creatures are known as metaphyta (plants) and metazoa (animals). Each individual of the many-celled species starts as a single cell, which divides and redivides over and over again. As the subdivision proceeds the cells become differentiated and specialized in various ways; the cells of each type go to make up some special kind of organ, which performs some specific sort of function. For example, a large number of cells of a very special sort unite to form a bone. The system or group of bones taken together serve to maintain the structural rigidity of the body, and at the same time serve as levers in the performance of various bodily movements. Similarly, epithelial cells unite to form the skin, etc. Each type serves to fulfil some special function in the life of the organism. [See Fig. 2.]

Organisms of the higher types perform a large number of distinct physiological processes, such as breathing, circulation of blood, digestion, secretion. Looked at from a broad standpoint these are all variations or modes of the general vital processes of maintenance and reproduction. Many of these subsidiary processes coöperate in a single act, as for example the various activities concerned in eating and in digestion. It is this coöperation of structures and processes that

constitutes the creature's *organization.* A creature, whether animal or plant, which is able to maintain itself and to reproduce through its structural arrangements and through the resulting coöperation of functions, is termed a *biological organism.* The complex system of structure and functions which characterizes living creatures is called *vital organization.*

A living organism is capable of growth and structural change. Its various parts (structure) are capable of performing the many acts or processes concerned in maintenance and reproduction, while the processes operate to create and preserve the structure. This interplay of structure and process, of organ and activity, extends in an endless series throughout the lifetime of the individual.

Classes of Vital Functions. — The processes of maintenance and reproduction are termed physiological or *vital functions.* These life processes are not due to a mysterious vital force or personality seated within the cell.[1] They are chemical and physical changes. Any specific vital act, such as eating, usually involves a number of different processes (e.g., chewing, salivation, swallowing, etc.). In the last analysis each of these component processes consists of one or more series of chemical and physical activities which take place within the organism. This transformation and displacement of substance (so far as we can determine) is fundamentally the same as that which occurs in the inorganic world. But owing to the complex constitution of protoplasm and its remarkable instability, there are certain characteristic differences between organisms and inorganic bodies. (1) The physiological activity of living beings is exceedingly complicated; (2) it affects the whole organism; and (3) it generally results in a better adjustment of the creature to his general situation.

While the vital functions may all be grouped together under the two general heads of maintenance and reproduction, it

[1] See Appendix, "Purpose in Organic Growth," p. 425; "Personification of Natural Phenomena," p. 433.

is convenient to subdivide them more specifically according to the special duties which they perform. Biologists recognize a great number of specific vital processes, such as breathing, circulation, digestion, sucking, grasping, chewing, leg movements, winking, and a host of others. A study of these would be interesting, but it belongs to general physiology and does not especially concern us here.

The generic functions of maintenance and reproduction are found to include a number of distinct sorts of process. We may distinguish altogether six great classes of vital functions:[1]

Organization (i.e., unitary interrelation of parts)
Nutrition
Growth (i.e., increase in size)
Regulation
Repair (or regeneration)
Reproduction

The meaning of *organization* and *reproduction* has already been explained, and the distinction between *nutrition* and *growth* is too obvious to require discussion. *Regulation* is a term used to denote the capacity of organisms to adjust themselves to variations in temperature, change of diet, and the like. *Repair* is their capacity to heal injuries and to make good the loss of parts occurring beyond the ordinary wear and tear of life.[2]

Psychologists are interested in the vital functions chiefly on account of the sharp contrast they offer to the functions which make up mental life. All the types of activities just listed serve primarily to *maintain the body substance and energy* of the organism. There are other types of process which serve to establish an interrelation between the organism and its environment. These are called *mental functions.*

[1] The term *function* as used here and elsewhere in the book means any *generic process*, or general kind of process. The term *process* is used for the *specific* kinds. Nutrition is a generic process which includes a great variety of specific processes such as chewing, swallowing, etc.

[2] The term *regeneration* is used when a new organ or part similar to the old is grown.

Mental Organization. — Most organisms, in addition to maintaining themselves and reproducing, are able to adapt themselves in some degree to the changes which take place in their environment, and many of them are able to produce very significant modifications of the environment.

The act of nutrition, in a narrow sense, involves merely absorption of matter and chemical energy from the immediate surroundings of the creature. But even simple one-celled organisms like amœba wander about and may be said to *explore* the environment for their nutriment. In the same way (though by means of far more complex processes) the human being enters into active relations with the world about him. He goes fishing or hunting or plants a garden to obtain food; or if he lives in a civilized community he walks over to the market and buys food. All this means the establishment of special kinds of relation with the environment. These activities serve to enlarge a man's points of contact with his surroundings; they often result in substituting one set of surroundings for another.

A crab which has lost its claw is able to grow a new one. This is merely a complicated vital process. But an animal belonging to a higher species may dodge to one side and thereby avoid a blow which would have resulted in severing his arm or leg. Activity of this type prevents the occurrence of injury instead of repairing its effects.

The functions of which these are examples are different in type from the functions of nutrition, repair, etc. They involve activity on the part of the organism in relation to certain features of the environment. But the interplay ordinarily reaches farther than this. When we build a house or use any sort of tool we are actively engaged in *modifying* our environment.

In man the 'environment' is tremendously broadened in both space and time. An architect living in New York may direct the construction of a building in San Francisco. The

environment upon which he acts extends at least over that range of territory. When a farmer plants his field in the spring he is acting in reference to the crops which will appear in the summer or fall. His environment is thus extended to include a section of the future.

All creatures are capable to some extent of adapting themselves to varying conditions in their environment, and the higher species are capable of modifying the world about them in many significant ways. In the more complex species this mutual interworking is accomplished by means of certain specialized structures within the creature — the nervous system and its terminal organs.[1] But even in the absence of such differentiated organs a similar interaction occurs. The protozoa, or one-celled animals, though they possess no differentiated nervous system, are able to receive impressions from the environment and to affect or alter the environment in many ways. They show at least a rudimentary differentiation of structure.

The interaction between an organism and its environment actually involves three stages: stimulation, adjustment, and response.[2] Each single interaction may be called an *experience*, and the sum-total of such experiences make up the *mental life* of the organism. The special structures and types of function which bring about the interaction constitute his *mental* (or *psychical*) *organization*.[3]

The relation between structure and function is different here from what we found in the case of vital organization. In mental life the functions do not build up the structure. Mental processes do not produce the nervous system, though they may modify its finer structure to some degree. The special organs concerned in mental life are the result of vital activity, working upon inherited organic material. They are

[1] See ch. iii. [2] See ch. v.

[3] Many writers restrict the terms *psychical* and *mental* to conscious states and processes.

due to the vital functions of reproduction and growth. In other words, mental life makes use of the structure built up by vital processes; it uses them not for growth or reproduction, but for adaptation to conditions in the outer world.

Classes of Mental Functions. — Any movement or internal change which occurs in an organism either directly or indirectly as a result of stimulation may be regarded as a 'response,' and the chain of activity involved in the experience constitutes a 'mental process' in the broadest sense of the term. If we take account of all the muscles and glands, as well as the special organs for receiving stimulation in man, we find a great number of distinct varieties of mental processes. But usually both the stimulation and the responsive activities occur in groups. Even such a simple response as winking involves the coöperation of muscles in both eye-lids, and in most cases it is brought about by stimulation of a large area in the eye.

Mental processes may be classified according to their complexity and with reference to the result which they accomplish. Among the simpler mental activities are winking, swallowing, yawning, and many other types. The complex forms of mental processes in man include such acts as walking, eating, display of anger, fear-activity, talking. In civilized man the manifestations of mentality become exceedingly complex; they embrace such intricate activities as planning out a vacation, running a business, and governing a nation. Each separate type of process may be investigated by observation and experiment. In later chapters we shall examine some of the distinctive varieties of mental activities; at present we are interested in determining the *general difference* between vital and mental processes.

We noticed that the vital functions may be grouped under a few general headings. In the same way the mental functions, despite their tremendous variety, may be grouped together into six general classes. The most fundamental

type of mental function is (1) *simple response* to stimulation. This is exhibited in the tropisms of the lower species and the reflexes of many-celled organisms. The knee-jerk, sneezing, and winking are typical reflexes. Higher in complexity are the two functions known as (2) *instinct* and (3) *habit*, which bring about adaptation through the coöperation of several reflex mechanisms. Instincts are built up by evolution in the race and transmitted to the individual by inheritance; habits are acquired separately by each individual. The suckling activity of infants is a typical instinct; opening a door and typewriting are examples of habit. A fourth class of mental processes is (4) *communication;* it is not more complex than habit or instinct, but it constitutes a distinct type, since it is concerned with the interrelation of separate organisms. An instance of this is answering a question. Still another type of mental function is (5) *rational action*, and last of all the far-reaching system of activity known as (6) *social conduct*.

These different classes of mental functions differ essentially from the vital processes already enumerated. There is, however, one border-line case. The locomotor functions, though generally concerned with the active relations of organisms to their environment, are sometimes wholly vital in character. The ordinary life condition of the one-celled paramecium is locomotor activity. Irrespective of external stimulation its cilia are in constant movement and it normally moves along in a spiral course. This enables it to take in food without any special adjustment. When it meets an obstacle it stops and reverses its movement; but its normal forward movement is *not a response to external stimulation;* it is as much a part of the creature's vital life as growth and nutrition. In higher organisms, however, locomotion usually occurs as a response to stimulation and may be classed among the instincts or habits.

For the sake of comparison a list of the two sorts of functions is given in Table II.

TABLE II. — VITAL AND MENTAL FUNCTIONS

Vital Functions	*Mental Functions*
Organization	Simple Response (Tropism and Reflex)
Nutrition	Instinct
Growth	Habit
Regulation	Communication
Repair	Rational Action
Reproduction	Conduct
Locomotion	

Evolution of Mental Life in Organisms. — Plants manifest very slight adaptation to their environment through stimulation and response. The growth of complexity from lower to higher species is almost wholly on the vital side. Among animals, however, there is a steady increase in complexity of adaptation through behavior as we ascend the scale of life; mental life assumes greater and greater importance as compared with vital life in the creature's total existence.

By far the most complex adaptations appear in man. He receives a countless variety of stimuli and his responses are tremendously intricate and far reaching. In civilized man mental life is the preponderant factor. Even the vital functions of nutrition and reproduction tend to become subordinated to impulses of mental life. The small boy who misses his dinner in order to see a base-ball game and the religious ascetic who renounces matrimony in order to cultivate holiness and humility, are merely exaggerated instances of the increasingly important rôle of mental life which we find in all higher beings.

Mental Life as Psychobiological Organization. — As explained in the first chapter, the province of psychology is the investigation of mental life. The psychologist seeks to understand the processes involved in stimulation and response, together with the modes of adjustment between these two. The entire chain of activity summed up in *stimulation*, plus *adjustment*, plus *response*, constitutes *experience*. The investigation of mental life is the study of experience, whether that

experience is accompanied by any discoverable consciousness or not.

In the human species the behavior phenomena, which are the active manifestation of mental life, are known to be accompanied by consciousness; in other cases its presence is doubtful. It is a question how far we should assume or infer the presence of consciousness when it is not directly reported. We are not especially concerned with this problem in the present book, since we are dealing with normal adult human beings, who are capable of reporting their conscious experiences. But if we seek to bring our human study into relation with animal psychology it is important to adopt a definite viewpoint.

While the presence of consciousness in subhuman animals is not demonstrated, the evidence indicates that the mental life of man is merely a higher or more complex form of the same sort of phenomena which appear in lower species. The evolution process is gradual, and starts at least with the protozoa. We seem justified, then, in assuming that conscious experience of some sort exists in all forms of animal life where behavior activity occurs.

On the other hand it is admitted by all investigators that no mental life has been observed except in animals and possibly plants. That is, the only beings which manifest mental life are biological organisms. Psychology, then, deals with *psychobiological organisms* and studies the phenomena of *psychobiological organization.*

Summary of Chapters I and II. — We may sum up briefly the points which have been brought out in these first two chapters. Psychology is the science of *mental life;* that is, the science which investigates the interrelations between organisms and their environment. Mental life consists in the adaptations of an organism to changing conditions of its environment, and the processes which bring about these adaptations constitute *experience.* Experience includes behavior

and consciousness — behavior being the action of the creature upon his environment, and consciousness an effect of environment on the creature.

Mental life is characteristic of living organisms. So far as we know, it belongs only to these. The organization of such beings is two-fold — *vital* and *mental*. Vital functions are those which serve to maintain the individual existence of an organism or to perpetuate the species. These functions may be classed under several general heads: *organization*, *nutrition*, *growth*, *regulation*, *repair*, and *reproduction*. Mental functions comprise all activities which bring about interaction between the organism and its environment through the chain of processes called *stimulation*, *adjustment*, and *response*. Mental functions may be grouped into several general classes: *simple response*, *instinct*, *habit*, *communication*, *rational action*, and *conduct*. The function *of locomotion* is both vital and mental. Mental life increases in importance as we ascend the scale of species. In man it may even replace the vital life as the chief factor of his existence.

Mental functions operate through certain bodily structures and organs which are built up by vital processes. Like other types of bodily structure these are composed of protoplasm. In all higher organisms, including man, the structure concerned in mental life is highly differentiated and consists of a complex connecting system of pathways called nerves and of specialized organs for receiving impressions and producing motor activity. The nervous system and its terminal organs constitute the *structural basis of mental life*.

Collateral Reading:

Moore, B., Origin and Nature of Life, esp. chs. 5–7, 9.
Osborn, H. F., Origin and Evolution of Life, Introduction.
Mathews, A. P., Physiological Chemistry, ch. 1.
McKendrick, J. G., Principles of Physiology, chs. 2, 3.
Wilson, E. B., The Cell.
Lickley, J. D., The Nervous System, ch. 1.
Morgan, C. C., Animal Life and Intelligence, 2d ed., chs. 1–3.

Hobhouse, L. T., Mind in Evolution, 2d ed., chs. 2, 3.
Parmelee, M., Science of Human Behavior, ch. 2.
Bawden, H. H., Evolution of Behavior, *Psychol. Review*, 1919, 26, 247–76.

Practical Exercises:

What has been your notion of "a mind"?

Describe some observations of your own on the repair of organisms (human or other).

Analyze the simple movements which compose some common habit; e.g. putting on a hat or taking off a glove.

CHAPTER III

THE NEURO-TERMINAL MECHANISM

Structural Basis of Mental Life. — The interaction between man and his environment is effected by means of certain specially differentiated cells which are peculiarly adapted to produce the chain of activity described in the preceding chapter. These cells may be divided into three classes.

(1) Cells of the first type — which include many very different varieties — are so constituted that they are set into activity (' stimulated ') by forces of one sort or another in the surrounding world or within the body. These are called receptor cells, or *receptors.* In some cases a number of differentiated cells form a special *receptor organ,* such as the eye or the ear.

(2) The second type of cell is peculiarly adapted to transmit the effect of stimulation in the form of impulses from the receptors to centers within the body, from one center to another, and from the centers toward the periphery of the body. These differentiated cells are called nerve cells or *neurons.*

(3) The third class of cells includes two varieties; one is peculiarly fitted to contract, the other to produce chemical substances (' secretions ') when affected by impulses from the neurons connected with them. Both types are called effector cells, or *effectors.* Effectors of the first sort are grouped together to form a *muscle* or contractile organ; those of the second sort constitute the *glands* or secretory organs.

The process of mental activity is based upon these three different organs — receptors, neurons, and effectors — which are arranged in a chain. The receptors and the effectors form the two ends of the chain and are called the *terminal organs;* the neurons which connect these terminals constitute a *nerv-*

ous arc. A nervous arc with its terminal organs form a *neuro-terminal circuit.* [Fig. 3.]

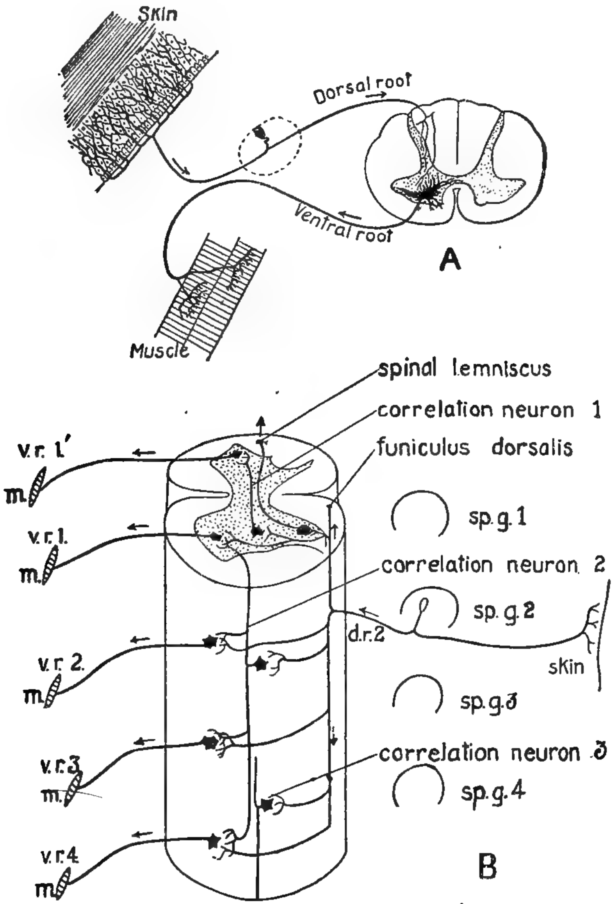

FIG. 3. — NEURO-TERMINAL CIRCUITS

A. Simple circuit from receptor in skin through cord to muscle. [From Herrick, modified after Van Gehuchten.]

B. Several circuits through cord; portion of complex circuit through higher centers indicated by vertical arrow at top; m = muscles. [From Herrick.]

The sum total of neurons in the body,[1] which consist of a net-work of interconnected arcs, is called the *nervous system.* The entire system of neurons and terminal organs, which constitutes the structural basis of mental life, may be called the *neuro-terminal mechanism.* In examining the structure of this very elaborate mechanism it will be convenient to describe the nervous system first, since it forms by far the most important part of the circuit.

Nervous System: Structure of the Neuron. — In all animals there are special paths of conduction for incoming and outgoing impulses. Even the protozoa have pathways within their body which conduct more readily than the rest of their protoplasm. In many-celled animals (metazoa) these lines of conduction are made up of neurons, which are composed of a highly specialized kind of protoplasm.

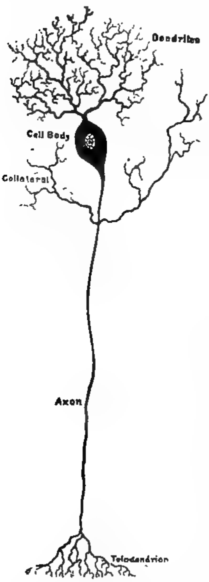

FIG. 4.—THE NEURON AND ITS PARTS

The general structure of the neuron is shown in the accompanying diagram. [Fig. 4.] In most other types of cell the central body is the largest and most significant part; but in the nerve cell the body is far less important than the projections or 'processes.' As the nerve cell grows, it sends out a long thread, called the *nerve fiber* or *axon*, usually with one or more branches called *collaterals.* The extremities of the axon and collaterals usually terminate in an arborization,[2] branching and rebranching like a tree. The arborization near the cell body is very intricate and is called the *dendrites;* the farther

[1] Together with certain other elements, such as connective tissue and glia.
[2] This arborization is sometimes called the *end brush.*

end of the axon is called the *telodendrion*. The cell body, axon, collaterals, telodendrion, and dendrites make up the *neuron*.

Neurons vary exceedingly in size. Some of the connecting sensory fibers in the spine are very short; they may be of microscopic size. Many neurons are very long; the sensory fibers from the toes to the spine are over two feet in length. There are several different sorts of neurons, varying in the size of their cell body and in the number and arrangement of their projections. They bear distinctive names, such as unipolar, bipolar, multipolar, pyramidal, Purkinje cells, etc. [Fig. 5.] Different types of neurons are found in the afferent (sensory) and efferent (motor) portions of the chain, and several distinct kinds occur in the central region.

Most of the growth of neurons takes places in embryonic life. At birth they have nearly reached their normal number and size. After birth relatively few neurons are added to the system, compared with the total number, and the growth of the existing neurons merely keeps pace with the general growth of the body.

Each nervous arc consists of several neurons connected together on the relay principle. One end of a sensory neuron extends out from the cell body till it almost reaches the surface of the body, where it connects with some receptor organ. In the other direction the same cell sends our projections which (in most cases) terminate in a mass of nervous tissues forming the spinal cord. Almost in immediate contact with this latter end is another neuron or neurons, which relay with a series of neurons extending up the spinal cord into the brain. This relay system serves to transmit an impulse from a receptor organ to the brain. A corresponding chain of relayed neurons transmits motor impulses from the brain to a muscle or gland. These two conducting lines, called sensory and motor paths respectively, are connected by the mass of central neurons which make up the brain itself. A shorter relay connects the two lines in the spinal cord. [See Fig. 3.]

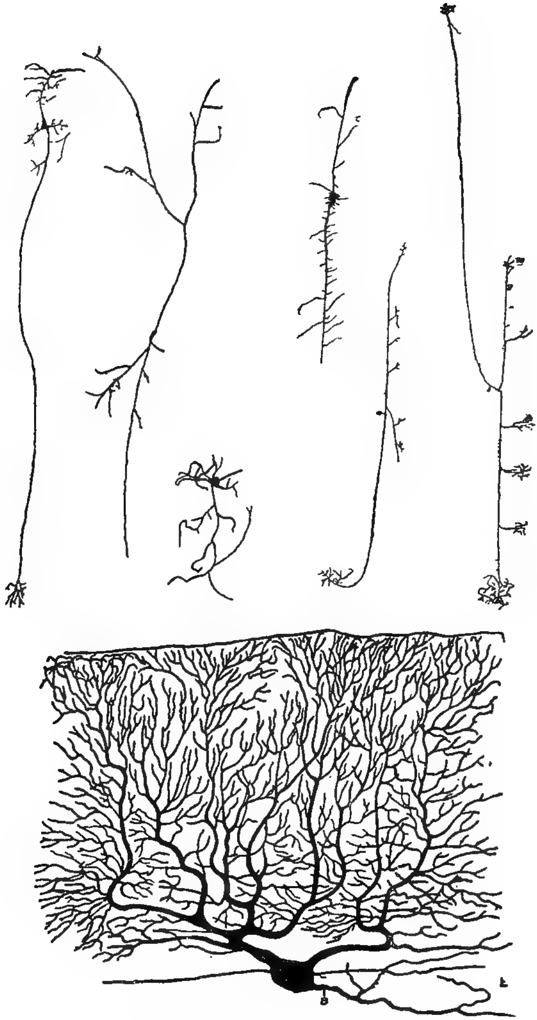

FIG. 5. — TYPES OF NEURONS

Above, six neurons of various types. Note the relative size of cell body and axon; the thickness of the axon is exaggerated and the finer arborization does not always show in the drawing.

Below, a Purkinje cell, greatly magnified. This type, found in the cerebellum, is characterized by elaborate branching of the dendrites; the axon (below, to the right) extends beyond the limits of the drawing. [From Thorndike; lower cell after Kölliker.]

FIG. 6. — SYNAPSES

A basket cell from the cerebellar cortex of a rat, showing synaptic connections of a single neuron (B) with several neurons (A). A typical synapse is shown at a. b = terminus of axon. c = axon of basket cell. [From Herrick, after Ramón y Cajal.]

The separate neurons which make up the circuit or line of conduction are not completely joined together. The telodendrionic arborization of one neuron intermeshes with the dendrites of the next, but according to the best observation there is no connecting filament between the two. The region where two neurons intermesh is called a *synapse*. There are several types of synapse. [Figs. 6, 7.]

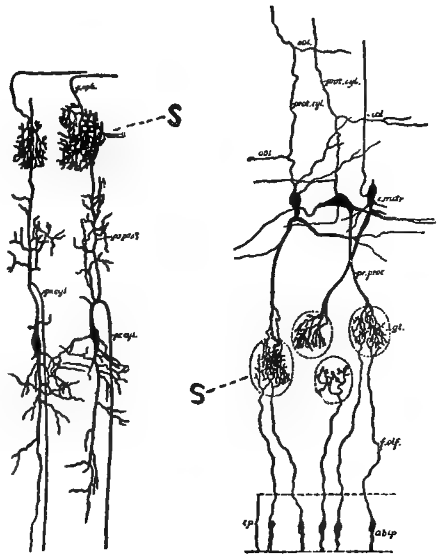

FIG. 7. — SYNAPSES

Various types of synapses; the synaptic regions are shown at S. [From Thorndike, after Van Gehuchten.]

In addition to the main lines of conduction along the axons, the collaterals furnish alternative paths of transmission. Within the brain especially the collaterals and arborization of one neuron form synapses with the dendrites of several other neurons, so that the whole brain presents a ramified mass — somewhat as an electric lighting system branches out in every direction. This branching and these alternative paths are especially significant in the interpretation of neural activity.

In some types of neuron the cell body lies slightly off of the direct line of transmission. [Cf. two right-hand cells in Fig. 5.] Possibly the nerve impulse in such cases does not pass through the cell body at all. This has led to the view that the cell body of the neurons is concerned chiefly with the growth and maintenance of the neurons and not essentially with the specialized function of nervous conduction.

Cerebrospinal System: General Plan. — The neurons are not scattered promiscuously through the body, but are massed in certain definite regions and lie side by side during the greater part of their course. The *brain* and *spinal cord,* in particular, consist of masses of neurons running parallel or connected end to end or crossing one another singly and in groups. These great masses of nerve substance comprise the *central nervous system.* Sensory and motor fibers connect the central system with the receptors and effectors respectively. The brain, cord, and these peripheral connections are called the *cerebrospinal system.* [Figs. 8, 9.] There are also certain groups of neurons which form a more or less independent system, though connected with the rest. This is called the sympathetic or *autonomic system,* which will be treated later. [Fig. 9.] The cerebrospinal and autonomic systems, taken together, constitute the *nervous system.*

The peripheral neurons which link up the receptors and effectors with the central system are not scattered and dispersed except near the terminals. They are grouped together

in bundles called *nerves*. For example, the separate afferent or *sensory* neuron fibers which originate in various parts of the retina in the eye unite to form a trunk line called the optic or second cranial nerve, which connects the eye with the optic center in the brain. Similarly the separate fibers from the auditory apparatus and semicircular canals in the ear run side by side in a bundle which forms the eighth cranial nerve. The afferent fibers which originate in the skin below the neck are collected into a number of bundles which terminate inside the spinal cord enclosed in the back-bone; two afferent or sensory bundles (i.e., one from the right side and one from the left) enter at each interstice between the vertebræ.

The outgoing neurons are gathered together in the same way. A bundle called an efferent or *motor* nerve, consisting of many separate nerve fibers, starts at some center in the brain or in the spinal cord and passes out through one of the openings between the vertebræ. These motor fibers run along side by side for a time in company with the sensory

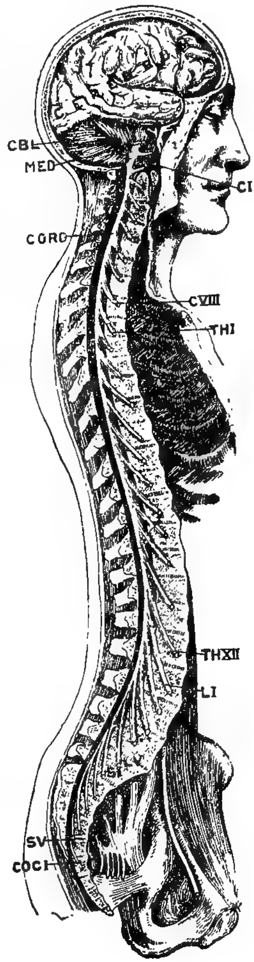

Fig. 8. — Central Cerebrospinal System

Above, the brain, including cerebrum, cerebellum (CBL), and medulla (MED). The spinal cord extends downward from medulla and is indicated by projecting nerves, cut off in the drawing; C I to C VIII = cervical nerves; TH I to TH XII = thoracic; L I to L V = lumbar; S I to S V = sacral; COC I = coccygeal.

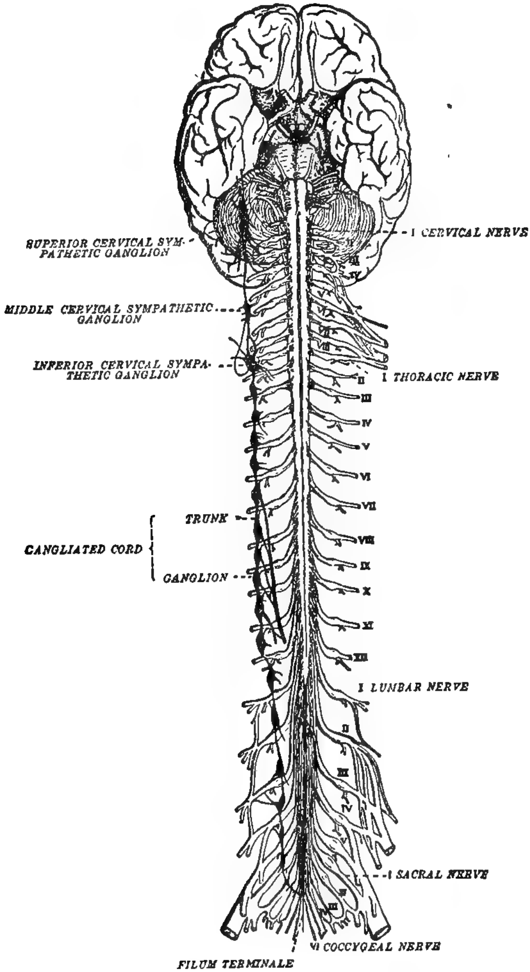

Fig. 9. — Cerebrospinal System and Sympathetic Ganglia

Ventral view of brain and cord. The sympathetic ganglia are shown in black at left. [From Herrick, after Allen Thompson and Rauber.]

fibers.[1] As they approach the terminal organ the separate fibers part company and lead to different parts of the muscle.

In the case of both sensory and motor nerves the separate fibers or neurons running side by side in the bundle are insulated from one another; a nerve impulse in transit does not pass across from one fiber to any of its parallel neighbors.

The bundles of fibers (nerves) originating in the head [Fig. 13] and cord [Fig. 9] are named and numbered with reference to their point of origin. In all there are 12 pairs of cranial nerves, and 31 double pairs (sensory and motor) of nerves leading to or from the spinal cord. Each nerve contains a great many separate fibers.

Owing to the collateral connections there are many more possible paths of conduction than there are separate lines of fibers. At certain paths in the chain of afferent neurons there are direct connections with efferent neurons. These occur, for example, at or near the point of entry into the cord. [See Fig. 3.] Through these collateral connections an incoming impulse may pass directly across and out to some motor organ without traveling up to the brain. In other words, it forms a *short-circuit.*

Of far greater importance, however, is the vast system of interconnections which exist in the brain. The human brain contains many billions of connecting neurons; these serve to connect sometimes one, sometimes another sensory neuron (or group of neurons) with now one, now another group of motor neurons. It would be difficult to calculate the total number of possible connections which might be made in the human brain. We may liken the brain to a telephone exchange, in which any one of thousands of subscribers may be joined up with any other. The analogy is not quite correct, since sensory neurons are never joined with other sensory neurons in complete circuit. If we suppose our telephone wires divided

[1] The sensory and motor nerves are sometimes called *centripetal* and *centrifugal,* respectively.

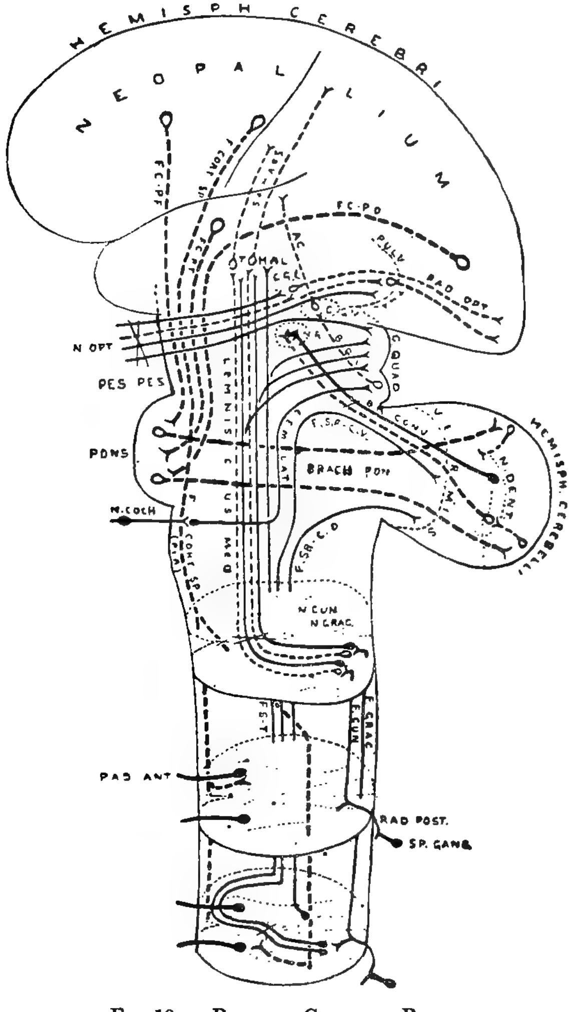

FIG. 10. — PATHS IN CORD AND BRAIN

Diagram showing course of some of the principal paths for conduction of afferent and efferent impulses. [From Bailey and Miller.]

into two groups, those which receive messages but do not respond, and those which make calls but never receive messages, the analogy will hold.

The Spinal Cord. — With exception of the nerves of the autonomic system[1] all the peripheral nerves of the body below the head, but including the neck, enter the back-bone or spine in the spaces between the separate vertebræ, as described above. The bones of the spine enclose a canal or channel, which contains a mass of neurons leading to and from the head and neurons leading laterally across. The mass of neurons within the spine form a long cord which extends from the coccyx to the head and is called the spinal *cord.* The cord is very small in diameter near the lower end, and increases in thickness (with some variations) as more nerves enter it at each successive vertebral opening. [See Fig. 9.]

The roots of the sensory nerves enter the dorsal (back) surface of the cord, while the motor nerves enter the ventral (front) surface. The paths connecting the peripheral nerves with the brain cross over in the cord from right to left or from left to right; so that the neurons terminating in the *left* side of the body connect with centers in the *right* side of the brain, and vice versa. The general course of the principal afferent and efferent paths in the cord and brain are shown diagrammatically in Fig. 10.

If we examine a cross-section of the cord [Fig. 11] we observe that the center appears grayish, and the surrounding portions light colored. The *gray matter*, as it is called, consists of cell bodies and fibers, while the surrounding *white matter* consists practically only of nerve fibers. The gray matter of the cord viewed in cross-section looks roughly like an H. The dorsal part of each 'upright' of the H contains sensory cells which receive the fibers of the right and left sensory roots respectively; the ventral portions of the uprights contain cells which send out the fibers of the motor roots.

[1] See p. 49.

The sensory and motor paths of the same side connect, completing the uprights of the H, and the sensory paths cross from side to side, forming the cross-bar of the H.

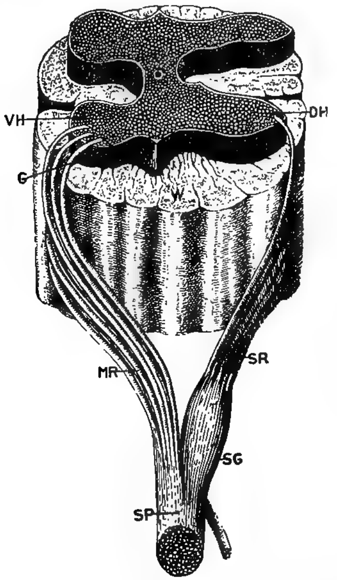

Fig. 11. — Cross-Section of Cord

Central gray matter (G) surrounded by white matter (W). From the ventral horn (VH) of gray matter emerges the motor root (MR) of a spinal nerve (SP); the sensory root (SR) of same nerve enters the dorsal horn (DH) which is more pointed than the ventral. Near the junction of the two roots is the spinal ganglion (SG) of sensory cell bodies.

The nerve shown in the figure is on the left side of body; the roots of the corresponding right-side nerve join the cord at the further pair of horns. [Modified from Testut.]

The nerve fibers which pass up and down the cord form the *white matter*. The separate nerves lose their identity within the cord; the fibers are grouped together into great masses called *tracts*, which are composed in part of continuations of the nerves, and in part of fibers of neurons belonging to the cord and brain.

We may note that the dorsal (sensory) ends of the H are usually *pointed* while the ventral (motor) ends are *blunt* and rounded. This difference is due to the fact that the cell bodies of the peripheral sensory neurons lie *outside* the cord.[1] Only the cell bodies of certain connecting sensory neurons lie within. The cell bodies of the peripheral motor neurons, on the contrary, lie inside the cord. Hence there is a larger mass of gray matter (cell bodies) in the ventral than in the dorsal region.

The Brain. — The higher connecting system, or *brain*, is exceedingly intricate in man. Practically the whole interior

[1] They form the *spinal ganglia*.

Fig. 12. — Model of Human Brain

Photograph of detachable model in papier-mâché by Th. L. Auzoux.

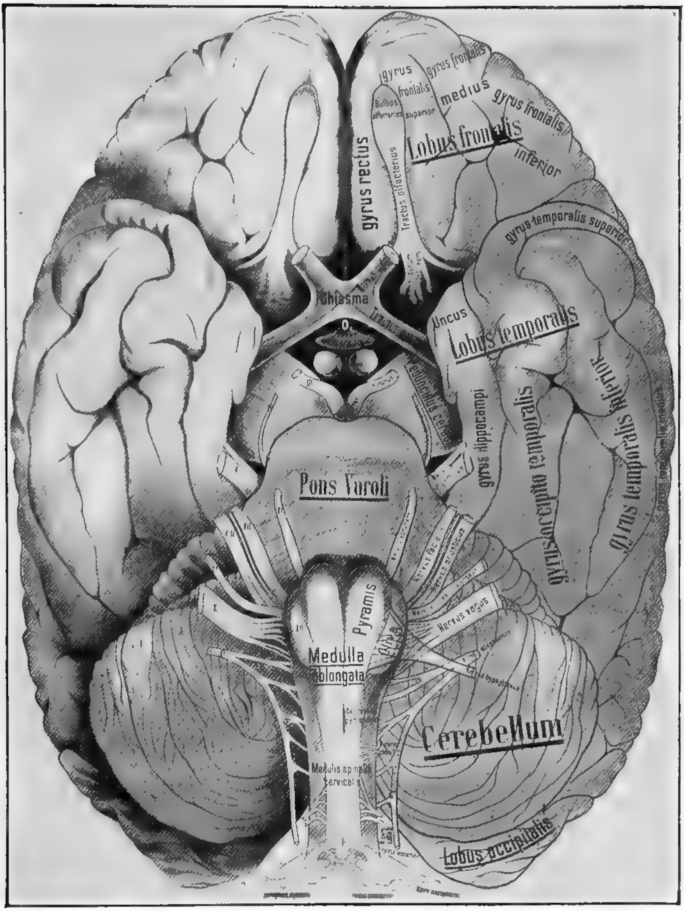

Fig. 13. — Base of Brain

From below, looking upwards. Cranial nerves are labeled (right) and numbered (left). [From Strümpell and Jakob.]

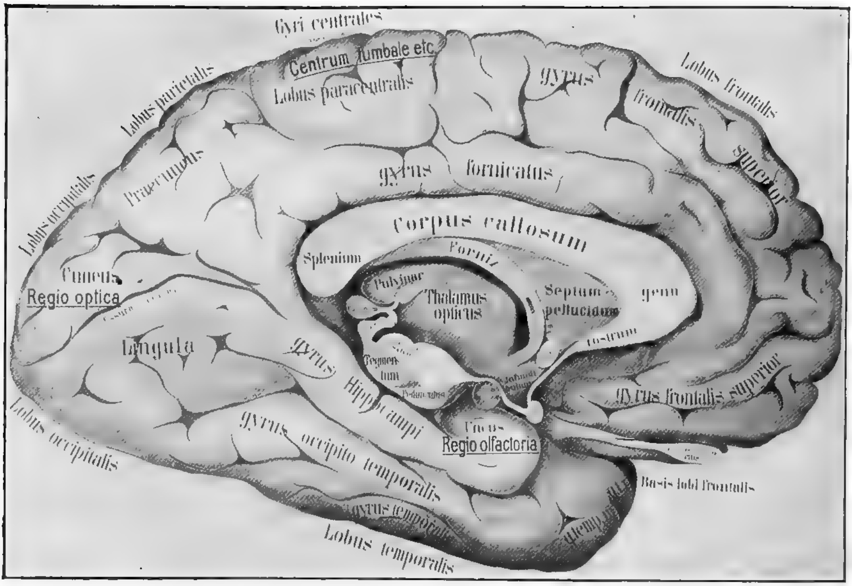

FIG. 14. — CROSS-SECTION OF BRAIN

Medial vertical section, looking toward left cerebral hemisphere. Basal masses (or ganglia) are shown below the callosum; surrounding these are the convolutions (gyri) of the cortex. [From Strümpell and Jakob.]

of the skull back of the mouth and above it is filled with a mass of neurons whose fibers interconnect in an exceedingly complex fashion. It has been estimated that there are at least 9280 million neurons in the cerebral cortex alone (the outer layer of the upper brain mass).

The lower part of the brain [Fig. 12, cf. Figs. 8 and 9][1] begins just above the level of the mouth as a swelling of the spinal cord; this enlargement is called the *medulla* oblongata. Back of the medulla and connected with it lies a spherical mass called the *cerebellum* [Fig. 13], while anterior to the medulla (forward) and somewhat above the cerebellum is a band-like mass crossing laterally called the *pons* Varolii.[2] The cerebellum is a coördinating center for movements concerned in maintaining equilibrium and general motor control of the body. Above the cerebellum and pons the medulla is lost in a number of odd-shaped masses of neurons called the *basal ganglia* or *basal masses* of nuclei [Figs. 13, 14], which are made up in part of fibers from the medulla prolonged upward, and partly of the cranial nerve fibers which connect with receptors and effectors in the head.

Of the twelve pairs of cranial nerves [Fig. 13], some are entirely sensory (the *optic, auditory, olfactory*), others wholly motor (the *oculomotor* and other nerves connecting with the eye muscles, the *hypoglossal* connecting with the tongue muscles), while several contain both sensory and motor fibers (the *facial*, for facial expression and for taste, the *trigeminal* for the skin receptors in the face and for the

[1] The relation of parts in the brain can scarcely be understood without examining a model. If one is available it should be studied instead of the figures given in the text. The same is true of the eye and ear, described in chapters ix and x.

[2] The medulla, cerebellum, and pons constitute the *hind-brain* ; certain of the basal masses form the *mid-brain* ; the cerebrum and remaining masses make up the *fore-brain*. These terms are based on the evolutionary history of the brain, which though of prime importance in comparative psychology lies beyond our present field. Consult references at end of chapter, especially Lickley and Donaldson.

muscles used in mastication). The cranial nerves terminate in the basal masses.

Above the basal masses and cerebellum, and covering them, are two great masses (right and left) called the *cerebrum* or *cerebral hemispheres*, which are separated by a deep cleft called the medial fissure. The outer (gray) layer of the cerebrum is called the *cortex*. The cortex is spread out directly under the skull, following its general contour.

The Cortex. — The cerebral cortex deserves special examination. [Figs. 15, 16.] The most striking feature about the cortex is its wrinkled character. The outer surface is creased into rounded ledges and fissures in various directions, so that there is considerably more 'exposed' area than if it were smooth.

The relation between white and gray matter in the cerebral hemispheres is the reverse of that in the cord: the *gray matter lies on the outside*, the white matter inside and beneath. Since the gray substance consists chiefly of cell bodies, it is evident that the outer layer or cortex of the cerebrum contains a mass of cells, while the underlying portion consists of fibers passing in various directions. The cortex is only 2 to 4 mm. in thickness, but on account of the folds it has a very large superficial area. It plays a rôle of great importance in mental life, particularly in the higher and more complex mental operations.

The two hemispheres are connected beneath by a great bridge of nerve fibers called the corpus *callosum*. The tracts of fibers which pass through the callosum generally terminate in corresponding regions of the two hemispheres; they thus serve to connect any given region in the left hemisphere with the symmetrically situated region in the right. The fibers which connect the two hemispheres are called *commissure fibers*. There are also tracts of fibers which connect one region in either hemisphere with other regions or centers in the same hemisphere. These are called *association* fibers and

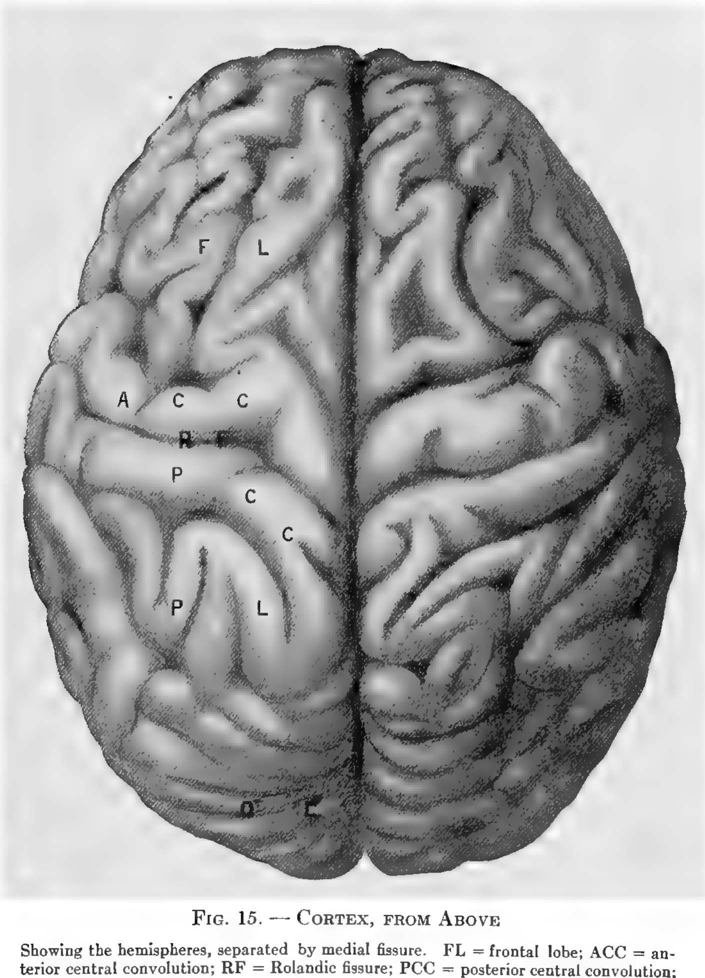

Fig. 15. — Cortex, from Above

Showing the hemispheres, separated by medial fissure. FL = frontal lobe; ACC = anterior central convolution; RF = Rolandic fissure; PCC = posterior central convolution; PL = parietal lobe; OL = occipital lobe.

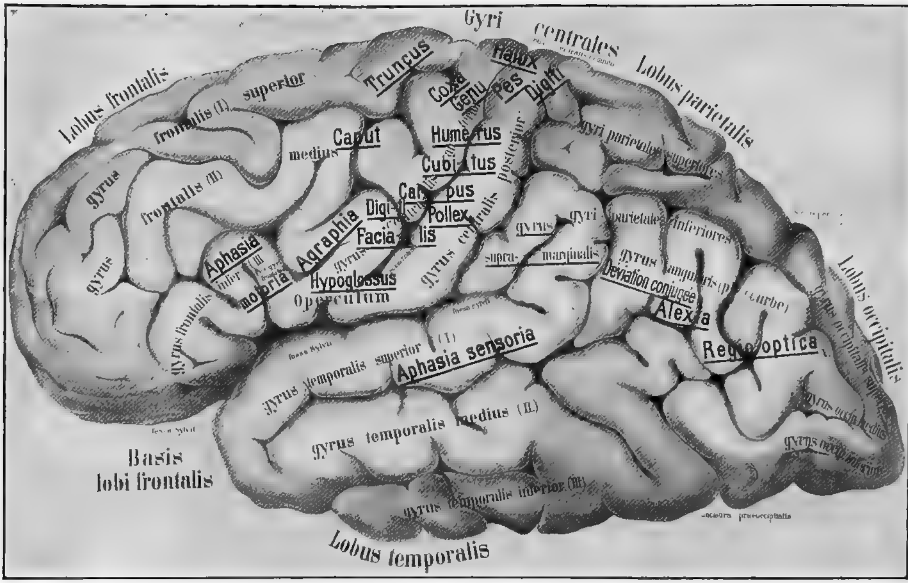

FIG. 16. — CORTEX, FROM LEFT SIDE

Showing convolutions (gyri) and fissures of left hemisphere. Centers for tactile sensations and corresponding motor centers bordering the Rolandic fissure are underscored. [From Strümpell and Jakob.]

tracts. The commissure and association fibers constitute the central or *internuncial* pathways of the hemispheres.

The cortex is divided by its fissures into several rather distinct masses called *lobes*. Morphologists have named these the *frontal*, *parietal*, *occipital*, and *temporal* lobes; they correspond in the two hemispheres. The dividing lines between the lobes in some cases are very clear. Notice (Figs. 15 and 16) the central or Rolandic fissure which separates the frontal from the parietal lobe, and the Sylvian fissure (Fig. 16) which separates the temporal lobe from these two. The boundaries of the occipital lobe are less definite. As a matter of fact the division into lobes does not necessarily denote any specific functional difference; they are named rather for convenience in topographical study. The same is true of the separate folds or *convolutions* into which each lobe is divided.

The cortex consists of quite a number of regions (centers or areas) in which fibers of one sort or another terminate. These regions may be grouped into two main classes, (*a*) *projection areas* and (*b*) *association areas*. The projection areas are the terminals of fibers coming from the primary sensory centers or nuclei in the basal masses and of fibers leading from the cortex to the primary motor centers in the basal masses. The association areas are centers for fibers coming together from two or more projection centers. The projection areas serve to integrate impulses coming from similar receptors and to coördinate impulses which operate groups of muscles, while the association areas serve to integrate and coördinate different sorts of sensory and motor impulses. A typical projection area is found in the region lying both front and back of the Rolandic fissure. The areas in front of this fissure are found to be centers for movement of different parts of the body, while those back of the same fissure are centers for sensory paths from the receptors in the skin. These two areas are motor and sensory projection centers, respectively. [Fig. 17.

Note the subdivision of these areas according to the different regions of the body with which they connect.]

Most of the projection areas are grouped together in three distinct regions of the cortex: (1) About the Rolandic fissure, extending from the crown of the head downward on the side.

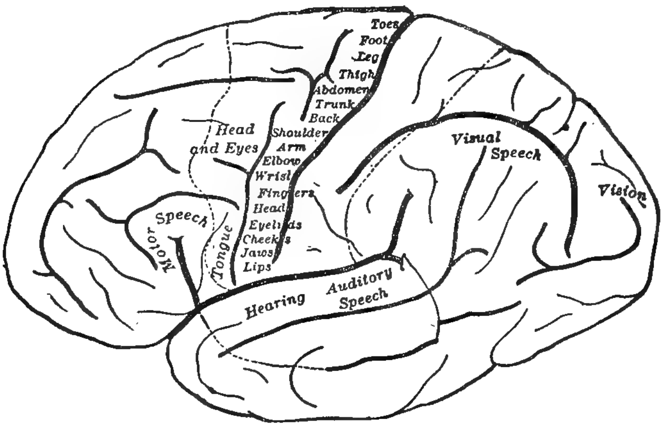

FIG. 17. — PROJECTION AREAS IN CORTEX

Outer surface of left hemisphere, viewed from left, showing projection areas along Rolandic fissure, and speech centers. [From Herrick, after Starr.]

(2) In the occipital lobe at the extreme back of the head. (3) In the underlying portion of the temporal lobe toward the center of the head.

The association areas lie between these. [Fig. 18.] (1) There is a large association region in the frontal lobe covering nearly the entire frontal portion of the cortex. The other association areas are not so definitely established. They are believed to include: (2) An association region comprising a large portion of the temporal lobe. (3) An association region in the frontal lobe near the top of the head. (4) An association region connecting (2) and (3). (5) A region in the fore part of the occipital lobe which is an extension of (2), (3), and (4).

These tracts contain the highest loops in the system of nervous arcs. They serve to connect together a great number of receptors and a great number of effectors and unite them into very complex circuits. The cerebral cortex is the 'inmost central link' in the chain of neurons which form the pathway from the receptors to the effectors.

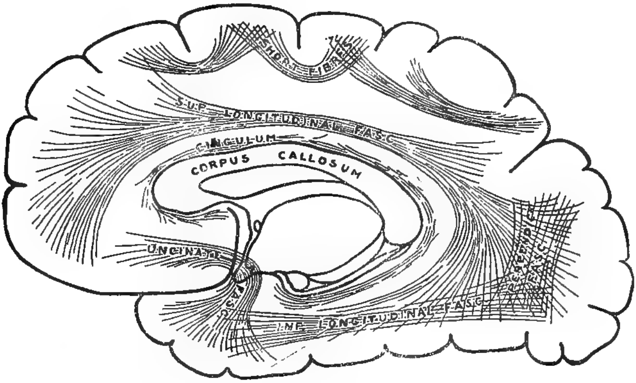

FIG. 18. — ASSOCIATION FIBERS IN CORTEX

[From Lickley.]

Autonomic System. — In addition to the nervous pathways leading through the spinal column to the brain, there are conducting neurons called sympathetic nerves or *sympathetic ganglia*, which lie outside the spine and somewhat anterior to it. [Fig. 19, cf. Fig. 9.] They consist of several collections of nerve cells (ganglia), one near each vertebra, with fibers which extend in various directions. (1) Fibers from these ganglia form a pathway to the internal organs for digestion, circulation, etc. (2) Each ganglion is connected with the next higher and next lower ganglion. (3) They are also connected with the cord by efferent fibers from the latter. The two sets of sympathetic ganglia (one on the right side, one on the left) extend up as far as the head. There are also

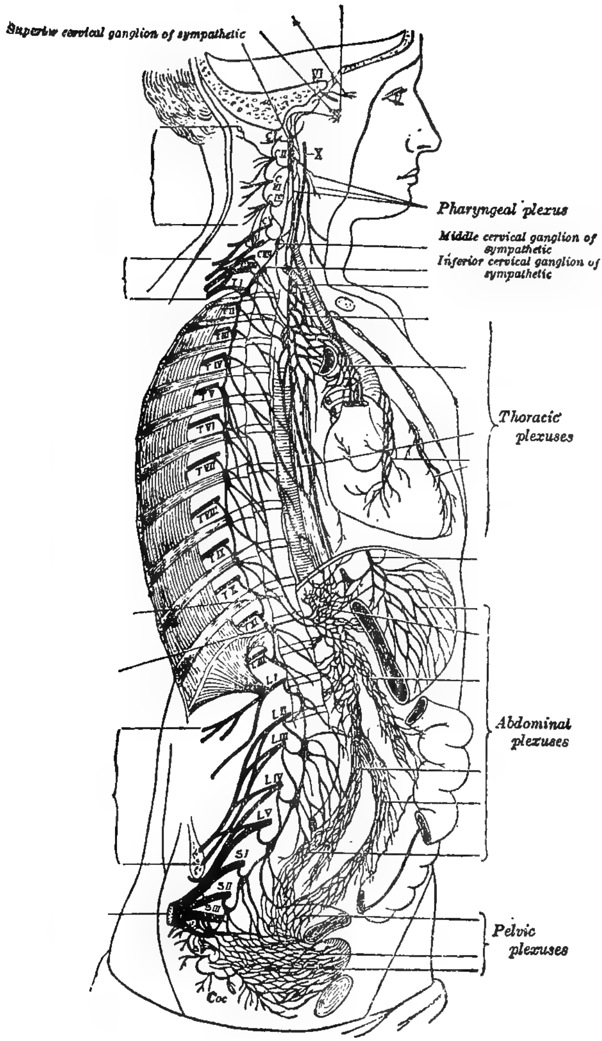

FIG. 19. — AUTONOMIC SYSTEM

Showing sympathetic ganglia and plexuses. Numbering of nerves corresponds to that of the cerebrospinal system; cf. Figs. 8, 9. [From Lickley, after Schwalbe.]

similar ganglia within the head, and important nerve groups (plexuses) in various parts of the body. The three main plexuses are (1) at the base of the heart, (2) in the upper part of the abdominal cavity, (3) in front of the lowest lumbar vertebra.

The sympathetic nerves serve to control the vital 'nutritive' processes of circulation, digestion, and breathing. The entire system of sympathetic ganglia and plexuses is called the *autonomic system*. Since the autonomic system is connected at a multitude of points with the cerebrospinal system, nerve impulses constantly pass from one to the other. Through this interplay our mental activities are constantly affecting our vital activities and our vital processes modify our mental processes. Thus the autonomic system, though chiefly concerned with vital functions, assists in the operations of mental life, especially in connection with the 'systemic' states which will be discussed later.

Terminal Organs. — The specialized cells which lie at the two extremes of the nervous pathways are not nerve cells, but they serve as intermediaries between the neurons and the forces of the environment. The cells at the beginning of the arc (*receptors*) are radically different in structure from those which lie at its terminus (*effectors*).

1. **Receptors.** — The receptor cells and receptor organs are of many different sorts. Each receptor is a specialized structure, which is capable of being affected by one (and usually by *only* one) of the many kinds of force which exist in the environment; when thus stimulated it starts a nerve impulse in the neighboring sensory neuron. We distinguish between *complex* receptors, such as the eye and the ear (which are composed of a number of different parts and consist of several different kinds of cells) and *simple* receptors, such as the Meissner and Krause corpuscles for cutaneous sensations. [See Figs. 30, 43, 54.]

The structure of the different sorts of receptors will be

treated in connection with the central sensory data which they yield (ch. ix, x). It should be noted that there are considerably more than five kinds of receptors, and that the historic classification into five senses is quite inadequate. The following different receptor organs, with corresponding senses, can certainly be distinguished: visual, auditory, static, olfactory, gustatory, tactile, warmth, cold, kinesthetic, and organic. In addition, the reception of pain stimuli can occur directly in the sensory pain-nerves without an intermediate receptor.

2. **Effectors: Muscles and Glands.** — The other class of terminal organs, known as *effectors*, lie at the peripheral terminals of the motor nerves. They comprise two very distinct types, *muscles* and *glands*.

A *muscle* consists of fibers of contractile tissue, bound together into a belt of strands and attached at each end to some bone or other tissue. [Fig. 20.] When a nerve impulse reaches the peripheral terminal of a motor nerve, the energy is transmitted to the strands of muscle and causes the whole muscle to contract in length and enlarge in diameter. The two ends of the muscle are thus brought nearer together and this produces a movement of the member to which the muscle is attached.[1]

For example, the biceps muscle of the arm is attached at the lower end to the radius bone some distance below the elbow. When this muscle contracts the radius is pulled upward and the whole forearm describes a circular arc with the elbow joint as center. Another muscle on the outer side of the elbow serves to pull the arm in the opposite direction and straighten it out again. The former movement is called flexion, the latter extension. Most muscles occur in pairs, one counteracting the other. Such pairs are termed *antagonistic* muscles.

Notice that in muscular activity the force is applied to the

[1] The nerve impulse starts a chemical process in the muscle, releasing energy. The total energy represented in muscular activity is far greater than that of the nerve energy which touches it off.

lever arm near the fulcrum, and *the long end of the lever performs the action.* A suit-case is lifted in the hand, while the contracting muscle operates near the elbow. This is the opposite of the ordinary use of the lever. In mechanics the force is usually applied at the long end of the lever arm, which en-

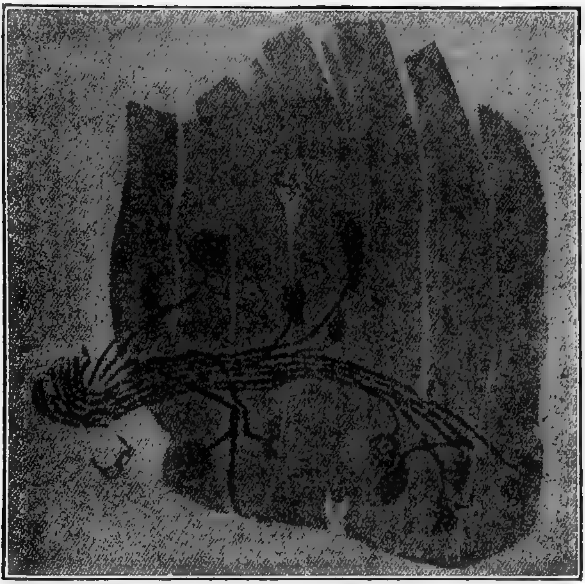

FIG. 20. — MUSCLE, WITH NERVE ENDINGS

Striate (voluntary) muscle, showing how motor nerve fibers terminate in the several strands. [From Dunlap.]

ables us to lift a heavy weight at the short end with comparatively slight effort. The fact that the great muscles in the arm are capable of raising very heavy weights at the long lever-end will give some idea of their extraordinary strength. Not all of the muscles are attached to bones; the eye muscles, for example, are attached at one end to the eyeball itself, which is not a bony structure.

The muscles of man are of two different structural types, called *striate* (striped) and *smooth*. The striate muscles, with exception of the cardiac or heart muscle, are all supplied by motor nerves of the cerebrospinal system. From the functional standpoint they are called *voluntary* muscles, because their activity is under the direct control of the brain mechanism. The smooth muscles are found in the internal organs and are connected with the autonomic system. Physiologically they are termed *non-voluntary* muscles. The cardiac muscle is striate, but it is supplied by the autonomic system and is classed as non-voluntary.[1]

Every definite movement which we make, whether great or small, is the result of muscular contraction. The muscles are located all over the body. Some are very large, others exceedingly minute, their size varying with the activities which they have to perform. Each muscle is separate from the others, though in some cases they cross. The complex movements which we make are not due directly to coöperation between the muscles concerned, but to coördination of impulses in the motor nerves and centers.

A *gland* is a mechanism for separating from the body fluids certain materials out of which it may also build up new chemical substances. This process is called *secretion*. A gland is composed of specialized cells, which bring about chemical analysis and synthesis among certain substances. One sort of gland acts upon the substances which compose saliva. When it operates, saliva is formed. Another sort of gland secretes tears, another urine, another sweat, etc. Some types of glands are furnished with ducts which carry off the secretions. Others, called the *ductless* glands, secrete various chemical substances (hormones) used in the growth and maintenance of the body.

[1] The terms *voluntary* and *non-voluntary* are somewhat confusing in this connection. The ear muscle is striate and supplied by cerebrospinal fibers, but in most men ear-twitching is not a voluntary act. The functional distinction is clearer if we divide muscles into *cerebrospinal* and *autonomic*.

When a nerve impulse passes along an efferent nerve which connects with a gland, the energy is transmitted to the gland and induces its specific activity. The secretory action of the tear glands may be started in a child by a motor impulse originating in the stimulus caused by bumping his head; in an adult the activity of the sweat glands may be set into operation by a motor impulse due to the perception of being in a dangerous situation. For the most part, glandular activity is connected with the vital processes and does not concern us here. But in situations like those just cited it constitutes an important factor in the interaction between the organism and its environment.

Summing up briefly, the *neuro-terminal mechanism* consists of the *nervous system* with its specialized terminal organs, the *receptors* and *effectors*. In this chapter we have examined the structure of this mechanism, particularly the *cerebrospinal* nervous system. In the following chapters we shall take up the modes of activity and operation of the neuro-terminal mechanism.

Collateral Reading:

Lickley, J. D., Nervous System, esp. chs. 2–7.
Herrick, C. J., Introduction to Neurology, chs. 3, 7–10, 16, 19.
Piersol, G. A., Human Anatomy, Vol. II., pp. 996–1380.
Ladd and Woodworth, Physiological Psychology, Part I, chs. 1–5, 9.
Dunlap, K., Psychobiology, chs. 3–8.
Donaldson, H. H., Growth of the Brain, chs. 7, 8, 10, 13.
Wilder, H. H., History of the Human Body, ch. 10.
Harris, D. F., Nerves, ch. 1.
Starling, E. H., Principles of Human Physiology, chs. 6, 7.
Stiles, P. G., The Nervous System and its Conservation, chs. 2, 5.
Angell, J. R., Psychology, ch. 2.
Judd, C. H., Psychology — General Introduction (2d ed.) chs. 2, 3.

Practical Exercises:

Describe (or name) the different sorts of muscular movement which you can observe in your face and head.

Analyze the location of touch, warmth, cold, and pain, as found in some region of your skin.

Report any instances of 'physical exhaustion,' indigestion, etc., due to worry, or of gloomy outlook due to digestive trouble.

CHAPTER IV

PHYSIOLOGY OF THE NEURON

Functional View of the Nervous System. — The nervous system comprises all the neurons in the body. Viewed as a working machine it consists of all possible circuits (nervous arcs) which may be joined up by combining various sensory, central, and motor neuron-chains. For psychologists the interest in this mechanism lies in the fact that it serves as a medium for the interaction between the organism and its environment. The environment affects the creature through the activity of the nervous mechanism, and the creature is able to produce changes in the environment by the same means. It is therefore of considerable importance for us to understand how the nervous mechanism works.

We shall examine the operation of the nervous system in the following order: (1) The activity of *individual neurons;* this includes an examination of the nature of the nerve impulse and the fundamental operations in nerve substance which produce differences in the impulse (ch. iv). (2) The specific operations which take place in *each part* of the nervous arc (ch. v). (3) The operation of the nervous arc *as a whole*, and the manner in which it serves to promote interaction between a creature and its environment (chs. vi, vii). The activity in the nervous arc, together with the muscular contractions, movements, and secretory changes which result from this activity, constitute the creature's *behavior*.

The Nerve Impulse: Intensity and Mode. — Very little is definitely known as yet regarding the nature of the specific activity which takes place in the neurons. The propagation of energy (called *nerve impulse*) certainly does not involve a transfer of physical particles, like the flow of water through a pipe. Neither does the phenomenon (so far as we can judge)

consist wholly in a wave motion of molecules, like sound or other effects of jarring which occur in the air or other media. Investigation has shown that electrical disturbances occur in the nerve substance during the passage of impulses; but there are indications also that chemical changes take place during the operation. Which of these processes is the characteristic feature of the nerve impulse is still in dispute.[1]

The *specific form* of any impulse seems to depend upon the specific form of activity in the receptors, which is determined by the nature of the stimulus, though this is also challenged. In all but the primary sensory neuron it certainly depends, in part at least, upon resistance at the synapses, and possibly upon other local factors. We may distinguish two sorts of variation in the impulse: differences in *intensity* and differences in *mode*.

(*a*) Intensity of the Nerve Impulse: The intensity of an impulse at any point is measured by the amount of activity at that point in a unit of time. Neurons have a certain range of capacity for receiving impulses. If the stimulus is very intense it affects the neuron only up to a certain limit, the remainder of the disturbance passing over into other tissues. In this respect the phenomenon does resemble the flow of water in a pipe; beyond a certain limit the conductor is unable to take care of the water — the surplus overflows into the surrounding territory. On the other hand if the stimulus is very weak it is unable to overcome the resistance at the junction between receptor and nerve, and does not excite activity in the sensory neuron at all. Similarly, a weak impulse in any neuron may be blocked by the resistance at its synapses, so that no excitation is produced in the next neuron. Thus we find an upper and a lower limit to the intensity of nerve impulses.

Where two impulses from different neurons come together

[1] See Appendix, "Nature and Modal Variations of the Nerve Impulse," p. 435.

in a single higher neuron of the chain, the impulse in the latter is a summation of the two, and may be more intense than either of its components.

(*b*) Mode of the Nerve Impulse: In neurons connected directly with receptors the impulse appears to vary also with the *mode* of stimulation. For example, the eye is capable of stimulation by light waves of any frequency between about 399 and 768 trillion per second. Waves in the neighborhood of 400 trillion produce a certain form of impulse which is experienced as ' red sensation ' when the effect reaches the brain. Waves in the neighborhood of 520 trillion produce a different effect known as yellow, etc. Different rates (modes) of wave vibration between the two limits produce varying modes of impulses in the optic nerve, while in most eyes waves which are more frequent than 769 or less frequent than 399 trillion per second produce no observable effect whatever. Similar variations in mode occur in the auditory and other sensory nerves. There are far greater modal differences between impulses in different sorts of sensory nerves than occur in nerves of the same class. For example, there are many modes of impulse in the optic nerve, but all these ' visual impulses ' resemble one another far more than they resemble any ' auditory impulse.'

The mode of the nerve impulse may be pictured as due to a specific *rate* or *frequency* in the succession of elementary impulses, just as the mode of a given light wave or sound wave is due to the frequency of ether vibrations or air vibrations. Or it may be conceived as a *variation in the chemical processes* which take place during neural activity.

What little information we possess regarding modal differences of neural activity is not obtained directly from measurement of impulses in the neurons. It is derived from the conscious experiences which follow stimulation, and these experiences indicate only the character of the impulse in the central cells which lie in the brain.

It is questioned indeed by many writers whether any modal differences exist among sensory impulses. The observed differences among sensations have been attributed to *specific* modes of *energy* supposed to characterize the different types of cells in various centers. According to another view they are due entirely to the *patterns* into which impulses are combined in the centers. The general relation between variations in stimuli and variations in sensations appear to support the view here outlined, that modal differences exist among impulses in the sensory nerves. We cannot regard the question as finally settled, however, till the precise nature of the nerve impulse is determined.[1]

The impulse in the motor nerves varies only in intensity; or if variation in mode exists it produces no noticeable effect on the muscles or glands. The intensity or degree of the motor impulse determines the rate of muscular contraction; if the muscle is called upon to perform more work (in lifting a weight), the same speed of muscular contraction requires a more intense degree of motor impulse. The only noticeable difference in mode among motor nerve impulses is between *direct* and *inhibitory* excitation. In certain cases, following an 'active' impulse, a 'checking' impulse appears to be sent down the same motor path, which counteracts the effect of the active excitation.

Fundamental Operations of Nerve Substance. — The substance which composes the neuron is capable of two specific types of operation in addition to those which bring about growth and repair. These specific properties of nerve are called *excitability* (or irritability) and *conductivity*. *Excitation* means that nerve substance is capable of being stirred to activity in some way as a result of receiving energy from without. *Conduction* means that after such excitation the nerve substance is capable of transmitting an impulse along the nerve

[1] See Appendix, "Nature and Modal Variations of the Nerve Impulse," p. 435.

fiber from one end of the axon to the other, and to the end of its collateral branches. In addition to excitation and conduction there are certain factors which serve to determine the nature of the nerve impulse in a given neuron, and which therefore belong among the fundamental operations of nerves. There are in all seven kinds of operation:

Excitation
Conduction
Retention
Metabolic variation
Summation
Distribution
Modification

1. **Excitation.** — Except in a few special cases the physical and chemical forces which operate in the environment do not act directly upon the nerve substance. They affect some one of the various sorts of specialized receptor organs, and the activity of these receptors produces excitation in the neighboring neuron. This process is known as stimulation (ch. v.). The excitation of all *succeeding* neurons in the chain consists of taking up an impulse from some other neuron. Activity is aroused in the sensory neurons of the cord (and in other secondary sensory neurons) by impulses received from the primary sensory neurons. The primary central neurons are excited by the sensory neurons in the cord (or by cranial sensory neurons); other central neurons receive their impulse from the primary central neurons. The motor neurons are excited either by an impulse from some central neuron or by sensory activity in the cord.

The process of excitation is not gradual, like the metabolism which takes place in ordinary vital functions (nutrition, etc.). It is of the ‘ explosive ’ type. The entire excitation is set up almost instantaneously, like touching off gunpowder. Thus the two kinds of activity (nutrition and excitation) which take place in nerve, though they may occur simultaneously, are quite distinct.

The excitation process works upon potential energy 'stored' in the nerve cell and uses it up. A nerve which has just received an excitation is incapable of receiving another immediately. The delay (called the *refractory period*) is short, in some cases only 0.002 second.

Much still remains to be discovered about the nature of excitation. It appears that the impulse aroused in a secondary neuron may at times be more intense than that in the neuron from which it derives the excitation. To this extent the gunpowder analogy holds. On the other hand, the intensity of excitation is apparently in most instances proportional to that of the stimulus, which would not be the case if the entire latent energy in each nerve were 'set off' by the stimulus or by the passage of an impulse from the preceding neuron. We have here two phenomena, which at present do not apparently quite harmonize: (1) The intensity of excitation is proportional to the intensity of stimulation. (2) The intensity of excitation varies according to the energy present in the neuron excited.

2. **Conduction.** — The second property of nerve substance is *conduction*, or ability to propagate impulses. When a neuron has been excited at one end, the impulse passes along the axon to the other end and travels also along the collaterals, so that the entire neuron is progressively excited. The rate of nerve conduction varies in different types of nerve and in different species of animals. In the sheathed nerves of the frog the rate is from 24 to 38 meters per second, while in unsheathed nerves it is much slower — from 0.2 to 8 meters per second. In the sheathed nerves of man the impulse may travel as rapidly as 125 meters per second[1] or perhaps even faster. The sheathing acts as an insulator and prevents loss of energy in transmission.

When the impulse reaches the far terminal of the neuron it

[1] Herrick, *Introd. to Neurol.*, 2d ed., p. 104. The rates of conduction in animals and man reported by various investigators differ considerably.

passes through the synapse into the next neuron, provided the substance of the synapse be in such condition as to permit the impulse to overcome the resistance at that point. It may also pass through the synapses of some of the collaterals into branch-paths. Conduction means that a neuron is capable of conducting an impulse (due to excitation) from a receiving end to a discharging end, and of discharging it into the next neuron.

In the living nervous system each neuron conducts impulses in *one direction* only: sensory neurons always transmit impulses away from the periphery *toward the center*, and motor neurons transmit from the center *toward the periphery*. In experiments upon isolated (excised) neurons it has been found that an impulse which starts in the middle of the neuron will travel in either direction. The fact that the living nerve conducts only in one direction is apparently due to something in the nature of the synapse.[1] Either the 'near terminal' is only able to receive impulses and is not capable of sending them back across the neighboring synapse; or the 'far terminal' is only able to transmit impulses into the synapse beyond and is not capable of receiving them; or both of these may be true. The synapses in any case serve to check the backward flow of the nerve impulse.[2] They are somewhat like the rotary gates which we find in some of our subway exits, which allow passengers to go out but prevent them from coming in.

The phenomenon of conduction concludes with the discharge of impulses at the further end. After this has taken place the discharging neuron becomes quiescent, and the neuron next in line takes up the impulse and propagates it along. It appears from physiological experiments upon nerves that if the discharge once begins, and a portion of the impulse

[1] There may also be a property of *living* nerve which renders the conduction irreversible in direction. The experiments showing reversibility were performed on *isolated* nerves. (See Herrick, op. cit., p. 103.)

[2] See L. Luciani, *Human Physiol.*, p. 201.

passes through, the transfer continues till all the energy passes over into the next neuron. In other words, if any energy at all passes across the synapse, the entire amount of kinetic energy represented by the impulse passes across, so that the first neuron is completely drained. This is known as the *all-or-none law*. It may be compared to the action of a syphon, which does not start to work till the liquid attains a certain level and then discharges the entire contents of the vessel.

It should be borne in mind that nerve conduction is not a transfer of *material substance* from end to end in the nerve. The phrase ' nerve current ' is only a figure of speech. The conduction is probably some sort of chemical change, accompanied by electrical disturbance, which is transmitted like a wave from point to point till it reaches the end of the neurons.

3. **Retention.** — The passage of a nerve impulse through the neuron tends to produce a change of some sort in the substance.[1] The exact nature of this alteration is not yet known; but it is known that nerve substance somehow retains the effects of excitation. When an excitation is repeated the outcome is often very different the second time from the first. The first excitation has left a *trace* or *set* which persists long after the impulse is gone. The effect of these retention traces is observed constantly in the behavior of animals and men as well as in one's own personal experiences. According to Lloyd Morgan (*Habit and Instinct*, p. 41), when a chick has picked up an inedible caterpillar and rejected it, if it comes upon a similar caterpillar again it will seldom pick it up a second time, though the stimulus and excitation are the same as before.

Observation of the learning process in man shows constant changes due to the persistence of traces. The same effect appears elsewhere. A memory image is apparently due to repetition of the mode which characterized some former im-

[1] See Appendix, "Retention, Metabolism, and Modification," p. 437.

pulse; but memory occurs when no external stimuli are present such as gave rise to the experience originally. The mode of the memory image is thus apparently determined by the retention trace. A slight retention effect is found also when the same sensory stimulus is repeated again and again; it is observed as a ' feeling of familiarity,' which characterizes the experience.

As a result of the retention of traces in the nerve substance new sensory impulses tend to assume the same mode as the old. The trace may exert a greater or lesser influence upon the new impulse according to circumstances. The retention effects in the optic nerve, for example, are generic as well as specific. Visual impulses exhibit a great variety of different modes, all of which belong to one general class — the ' luminous.' In the adult, who has received innumerable visual stimuli, any excitation of the optic nerve tends to take on the generic ' luminous ' mode. A blow on the head results in our seeing a flash or splurge of light.

The retention effect in the central and motor neurons consists in part at least in the formation of a more or less permanent connection at certain synapses. When the resistance at a synapse is overcome and the impulse passes across, the path becomes ' worn down ' so that subsequent impulses pass more readily along this path than before. Permanent lines of lessened resistance are thus established, which bring about the formation of habits.

It is difficult to account for the variety of alternative movements which occur in many habitual activities on this basis entirely. A slight variation in the stimulus will at times alter the whole character of the act. In typewriting, each of the different letters seen in the manuscript leads to a specific movement. It seems probable that the quality or mode of the stimulus is a factor in determining the combination of movements which enter into a given response.

The retention of the traces of former modes of excitation

in the central and motor neurons would account for this, even though the mode of the impulse has no effect upon muscular contraction. If a motor neuron has once received an impulse of a certain mode, it will retain the effect of this mode. If later on another impulse of the same mode occurs in the central neurons, it will pass into a motor neuron which has retained this kind of trace, rather than into other neurons whose 'set' is different. We may conceive of the process by the analogy of several doors, each of which is opened by a certain particular key; or we may liken the motor neurons to a set of tuning forks, each of which vibrates sympathetically to a certain rate. However we picture it, the essential feature of the process is that one motor neuron or another receives the central impulse according as its retention trace is the same in mode as the present central impulse.

There has been considerable dispute as to whether retention effects are ineradicable — whether every impulse leaves a permanent mark in the nerve substance. No definite answer to this question can be given at present. There are indications that motor tendencies continue to persist even though the specific connections have not been made for a long time. Once a person has learned to swim, to telegraph, or to perform any other motor act, the effect of such motor combinations is observed after years of disuse. There is also abundant evidence to show that a retention effect in the *central* neurons may persist for many years. Instances are known where very old persons have recalled incidents of early youth and childhood, which had in all probability never been revived in the meanwhile. If a chance connection shows this persistence in a few cases, there are probably many more which only await the proper excitation.

Some writers go so far as to assert that every excitation leaves a permanent effect — that no experience is ever really forgotten. This sweeping assertion, however, goes far beyond the evidence, since in the nature of things it is only the

uneradicated effects that are brought to light. For every effect which lasts to old age there may be a thousand others which time has wiped out entirely. The evidence certainly indicates that many retention effects persist in the neurons of the brain which may never actually operate as motor tendencies or memory images. But the retention effects of weaker excitations are probably effaced in the course of time by other more powerful impulses.

4. **Metabolic Variation.** — In addition to the retention effect another sort of change occurs in the neurons. This is due to variations in the metabolic condition of the nerve substance itself. Some of the receptors and effectors are highly susceptible to metabolic change. The rods and cones of the retina are greatly fatigued by prolonged stimulation with bright light. The muscles of the arm are fatigued by prolonged activity. These metabolic changes in the terminal organs frequently play an important part in the mental life of man.

Recent physiological investigation indicates that the *nerve substance* also undergoes some katabolism as the result of the conduction of nervous impulses, but that this metabolism is very slight. On the other hand, the substance at the synapses appears quite susceptible to metabolic change. The metabolic condition of the synapses determines the ease of discharge of a nerve impulse from one neuron to the next. If a synapse is fatigued, the discharge is impeded and may be entirely prevented. If a neuron has several collaterals besides the main axon terminal, the impulse may be inhibited from passing over the synapses at the end of some of these on account of their highly katabolic condition and will be shunted into others which afford lines of lesser resistance. [Fig. 21.]

This variation of metabolic condition at the synapses accounts in part for the fact that the same initial excitation will lead at one time to one action, at another time to another. When a friend invites you to go walking with him, sometimes you accept, at other times you decline. The variation in your

response is due to the different paths which the nerve current takes on the various occasions and to the specific brain areas which it traverses.

In prolonged thinking a continuous process of katabolism takes place in the brain. It results in fatigue and finally in exhaustion. The period of sleep serves to restore the metabolic equilibrium. If we take as standard of measurement the average metabolic condition of the synapses, any change toward greater katabolism in a given synapse means the checking or complete inhibition of discharge through that synapse, and any change toward anabolism means facilitation of discharge in that direction. These are important factors in the formation of habits (ch. vii).

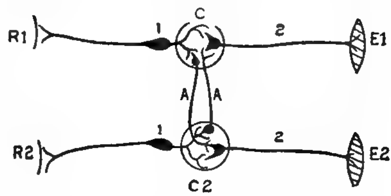

FIG. 21. — ALTERNATIVE NERVE PATHS

Impulse from receptor R1, when it reaches center C1, may either pass directly to effector E1, or be shunted to center C2 and thence to effector E2; it may also be distributed to both paths. Similarly for R2. A, A = association neurons. [From Herrick.]

The metabolic condition of the synapses is one factor in determining the course of nerve impulses; it is distinct from the retention effect in nerve substance. The former effect (fatigue and its opposite) is more transitory than the latter.

5. **Summation of Impulses.** — The nature of the nerve impulse is altered when several impulses from different neurons unite together in a single higher neuron. In the central system the dendrites of a neuron are so spread out that they are able to receive impulses from several separate neurons.

We have noticed that the fibers of the sensory neurons extend side by side without contact, somewhat like the separate wires in an underground telephone cable. But when the impulses which travel over them reach the brain the central neurons collect together impulses from many of these separate paths. This is illustrated in some of our experiences. When

we perceive a human face as a single object, or observe a table or an orange or any other object, the integrated perception is apparently due to the gathering together of many impulses which were received by separate rods and cones in the retina and transmitted separately to the visual center. When we perceive an orange as heavy, smooth, yellow, and sweet-scented, separate impulses from certain muscle receptors, touch corpuscles, retinal cones, and olfactory spindles are

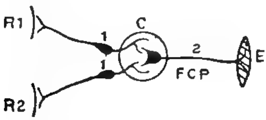

Fig. 22. — Summation of Nerve Impulses

Simultaneous impulses from two receptors R1, R2, combine in center C, and the summated impulse travels to effector E. FCP = final common path. [From Herrick.]

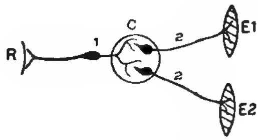

Fig. 23. — Distribution of the Nerve Impulse

Impulse from receptor R branches at center C and is distributed over paths leading to two effectors E1, E2. [From Herrick.]

united in the same way. The result in each case is a complex impulse due to the combination of separate sensory impulses. This combination is called *summation* or fusion. [Fig. 22.]

The motor impulses which produce compound reflexes are due to summation of sensory impulses with impulses from lower centers. In instinctive and intelligent activity the complex motor impulses are due to summation of sensory impulses which takes place in the centers of the brain.

6. Distribution of Impulses. — The collaterals of the sensory and central neurons serve to disperse nerve impulses as well as to gather them together. Most of these neurons branch out and are provided with several end-synapses. As a result of retention and metabolic variation, part of the impulse may pass over into one higher neuron and part into another. [Fig. 23, cf. Fig. 21.] The effect is to arouse several central or motor activities at once. This gives rise to com-

plex central and motor processes. This property of neural activity is called *distribution of impulses.*

When we perform any complicated act, such as guiding an automobile or talking, the central impulses are distributed into several motor paths. In running the car, our muscles control the steering wheel, gas, brake, and horn all at the same time; in talking, our lips, tongue, and diaphragm muscles are all simultaneously innervated. A distribution of the impulse occurs also in certain reflexes, such as coughing, where part of the impulse passes over immediately into the motor path, producing the reflex, while part is carried along to the brain, producing a sensation of tickling in the throat.

Retention and metabolic variation may result in alternation of paths, whereby the *whole* impulse is discharged at one time into one channel, at another time into another. In such cases no distribution occurs.

7. **Modification of Impulses.** — In addition to the six operations of nerve just examined, we may reckon as a distinct factor the modifying influence of one impulse upon another when the two are summated. In like manner, when an impulse passes into a neuron which has been affected by previous impulses, the retention trace apparently modifies its mode.

In physics, when two forces of the same sort (such as sound waves) come together, they modify each other; if the two are in opposite phases they may neutralize each other in part, producing a less intense sound. To what extent such modification occurs in nerve impulses is not yet known. The evidence from subjective experience leads us to believe that it is quite general. A number of experiences of a similar sort combine to produce a 'generic image,' in which the common features are prominent and dissimilar features are smoothed over. For example, having observed a number of horses, differing in color, shape, and various minor characters, we experience a general image of *horse,* in which the individual dif-

ferences tend to disappear. Our thoughts involve an even greater transformation of the sensory data (ch. xv).

It may be assumed that the transformations observed in conscious experiences are the subjective equivalent of modifications of nerve impulses in the neurons of the cerebral cortex. If the retention trace in a certain neuron has become deeply embedded through repetition, it may greatly modify any new impulse which passes into that neuron. This would explain the fact that the optic nerve, however it be stimulated, always yields impressions of light.

Modification is not so evidently an independent operation as the other six forms of neural activity. It may prove to be merely a phase of summation. In the present state of our knowledge it seems best to regard it as a distinct property of nerve.

Summary of Nerve Physiology. — The nerve impulse appears to vary in two independent ways — *mode* and *intensity*. These variations are determined apparently by the nature of the stimuli and by the characteristic operations of nerve substances. We observe seven types of operations in nerve:

Excitation means that the nerve is capable of receiving an impulse of some specific mode and intensity.

Conduction means that when once a nerve impulse is excited in a neuron it tends to propagate over the entire length of the axon and collaterals, and to discharge into the further-lying synapses.

Retention means that the mode of a nerve impulse tends to leave a 'trace' or 'set' of some sort in the nerve substance, whereby any succeeding impulse will tend to conform more or less to this same mode.

Metabolic variation means that the nerve substance and the interneural substance at the synapses are subject to katabolic and anabolic changes, the former being due to activity, the latter to rest. Katabolism checks or inhibits discharge

through the given synapse; anabolism facilitates the passage of the impulse.

Summation means that impulses from two or more neurons may be gathered into one single neuron further along in the chain, which produces a complex impulse in the latter neuron. The effect occurs sometimes in the motor neurons, but its most important operation is in the brain centers.

Distribution means that a single impulse in one neuron may pass simultaneously to two or more neurons further along in the chain. This results in complex motor activity.

Modification means that the mode of an impulse is altered when it combines with another impulse, or that it may be altered by the retention trace in the neurons through which it passes.

Collateral Reading:

Herrick, C. J., Introduction to Neurology, chs. 6, 20.
Ladd and Woodworth, Physiological Psychology, Part I, chs. 6, 11.
Dearborn, G. V. N., What a Student of Elementary Psychology should be Taught concerning the Function of the Nervous System, *J. of Psychol. and Neurol.*, 1914, **21**, 35–44.
Halliburton, W. D., Handbook of Physiology, chs. 14, 16.
Bayliss, W. M., Principles of General Physiology, ch. 15.
Starling, E. H., Principles of Human Physiology, ch. 6.
Harris, D. F., Nerves, ch. 2.
Lucas, K., Conduction of the Nervous Impulse.
Verworn, M., Irritability, ch. 6.
Tashiro, S., A Chemical Sign of Life, ch. 6.
Semon, R., Die Mneme.

Practical Exercises:

Examine one of your earliest *definite* childhood recollections: (*a*) What details are vivid, what are vague. (*b*) Your age at the time, and how you fix the date. (*c*) Whether any details were possibly supplied by some one's narrating the occurrence or by your "reading them in" more recently. (*d*) Any assignable reason why this recollection should have persisted.

When sleepy or mentally fatigued, try to work out some difficult problem; analyze the experience.

Describe the "feeling of familiarity" which accompanies your experience of seeing an old friend or a well-known building.

CHAPTER V

STIMULATION, ADJUSTMENT, AND RESPONSE

The Nervous Arc and its Segments. — The seven properties of nerve just mentioned belong to all neurons. But the operation of any single neuron means nothing for mental life apart from its connection with other neurons and with the terminal organs. The specific function of the nervous system is to mediate between the organism and its environment. This is accomplished by the activity of the nervous arc, consisting of three segments.

Certain effects are produced in the afferent neurons (sensory segment) by conditions in the world outside or by conditions within the body; as a result, the efferent neurons (motor segment) arouse certain activities in the effectors, which modify the environment. These two sorts of effects are coördinated by the connecting neurons (central segment), in such a way that the movements and glandular activity of the creature at any given time are more or less appropriate (adapted) to the situation which confronts him. When food is available and he is hungry he acts so as to secure the food. When danger appears he runs away.

The sensory segment of the nervous arc consists of one or more neurons placed end to end, so as to form a pathway which connects a receptor organ with some center in the spinal cord or brain. The central segment of the arc consists of one or more neurons forming a pathway which connects the central (inner) end of the sensory path with the inner end of a motor path. The motor segment is a pathway which starts at a center in the brain or cord and leads to some muscle or gland. If we take into account the receptor and effector organs, the circuit consists of five parts: *receptor*, *sensory* (or

initial) *path*, *central* (or *internuncial*) *path*, *motor* (or *end*) *path*, *effector organ*.

As a matter of fact the central connections are so intricate that it is impossible to distinguish any given nervous arc from certain others. When we are watching a foot-ball game, the optic nerve receives a steady stream of visual stimuli. In such cases the central connection from the optic nerve may lead sometimes into one motor path, when we clap our hands; at other times into quite a different motor path, when we shout and yell; or into still a third path, when we jump up and down in excitement. But these same motor paths for hand-clapping, shouting, or jumping, may in other cases be joined up with the auditory nerve; we may respond by any one of these modes of expression when we listen to an exciting story.[1] The motor section is often called the ' common end-path ' of the impulse. The sensory section is just as truly a common initial-path.

The simplest arcs of all terminate in the spinal cord. In these the central part may be entirely lacking. The nerve impulse goes up the sensory path to the cord, and thence passes directly over into the motor path and so out to the effector. A simple arc of this sort is called a *spinal circuit*, and the nervous action is called a *spinal reflex*. Most circuits lead up the spinal cord into the brain, or if they start in the head they form a brain circuit. The circuits which pass through the brain are of various degrees of complexity. In the case of a well-organized habit the path is probably comparatively simple. In planning how to build a house or write a book or organize a business, some of the circuits may include long chains of neurons in the central portion of the arc.

Operation of Each Segment. — The circuit of neural activity which operates in any nervous arc or in a complex sys-

[1] Fig. 21 on p. 67 illustrates these alternative connections in a schematic way.

tem of arcs is known as *behavior;* but every instance of behavior includes three separate stages, which correspond to the parts of the nervous arc. In discussing the operations of the three segments of the arc, it will be convenient to treat the central part last. The three operations are called *Stimulation, Response,* and *Adjustment.* (1) *Stimulation* is the effect of external or bodily conditions upon the sensory part of the nervous arc. (2) *Response* is the effect of the motor portions of the arc upon the effectors and upon the environment. (3) *Adjustment* includes (*a*) the collection of sensory impulses at the centers and (*b*) distribution of out-going impulses from the centers into appropriate motor channels. The former is called *Integration,* the latter *Coördination.*

1. Stimulation

Nature of Stimulation. — So far as we know, a nerve impulse never starts within a neuron except as the result of excitation from outside that neuron. Sensory neurons receive impulses from the receptors or from other sensory neurons. Motor and central neurons (save perhaps in exceptional cases) receive all their impulses from sensory neurons or from other motor or central neurons. They are not directly excited by activities in the other body tissues.

Thus the origin of every ordinary nerve impulse may be traced directly or indirectly to some force outside the nervous system acting upon the peripheral endings of sensory neurons. This *initial* excitation is called *stimulation.* Not all stimuli are due to forces outside of the body. Activity of the digestive and other internal organs stimulates the receptors and sensory nerves which lie in these regions; and muscular activity stimulates receptors and sensory nerves connected with the muscles, tendons, and joints.

Most nerve impulses are aroused by activity in a receptor organ; but certain pain nerves terminate peripherally in the epithelial tissues and have no special receptors; activity in

these tissues stimulates the pain nerves directly. (These are called *free nerve endings.*)

We may state, then, as a general law, that all neural activity originates outside of the nervous system through the process of excitation. The *original excitation* of a sensory neuron by a non-neural force is called *stimulation,* and the force which causes the process of stimulation is termed a *stimulus.*

Rôle of the Stimulus. — Stimuli vary in intensity, mode (quality), extent, and duration. But the two latter variations affect the impulse in a different way from the first two. (1) An extended stimulus does not alter the nature of the impulse in any single sensory neuron, but it may stimulate a *great number* of receptors and sensory neurons, and the resulting impulses may be summated at the centers. (2) If a stimulus continues for some time, the duration affects the impulse in much the same way that previous stimuli affect a later stimulus. We may therefore treat an enduring stimulus as if it were made up of a series of momentary stimuli, each without appreciable duration. So far as the effect of stimulation upon any single sensory impulse is concerned, extent and duration may be ruled out. These variations affect the central and motor operations only. The only variations which we need consider in connection with stimulation are *intensity* and *mode.* We have already noticed these factors in discussing the nerve impulse (ch. iv). Differences of intensity among stimuli produce differences of intensity in the impulses, and modal differences among stimuli lead to modal differences in the impulses.

(*a*) Mode: Each type of receptor is capable of being stimulated by a specific kind of force, and its capacity is limited to a certain range of modes of that force. Thus the visual receptors in the eye are ordinarily affected only by light waves, and only by a certain range among these. In certain cases a different kind of force than the usual stimulus produces an

effect upon a receptor; the eye may be stimulated visually by rubbing or pressing the eyeball. These unusual modes are called *inadequate* stimuli, while the normal kinds are termed *adequate* stimuli.

Corresponding to the different kinds of stimulation in the various types of receptor and to different modes of stimulation in receptors of the same type, the nerve impulse assumes different forms, or modes, as described in chapter iv.[1] Where stimuli are so different that they act upon different kinds of receptors the resulting sensory impulses are quite heterogeneous. They are centrally observed as sensations of touch, sight, hearing, etc. The modal differences within the range of the *same* receptor may be illustrated by the central impulses (sensations) due to red, green, and other visual stimuli.

So far as we know, any sensory nerve might readily transmit any other kind of impulse besides its own, if connected with appropriate receptors. The optic nerve, for instance, might transmit olfactory impulses if connected with the receptors in the nose. As a matter of fact, however, the optic nerve has been connected from the outset with the retinal rods and cones, and practically all the impulses which it has transmitted have been of the visual type. These impulses have produced a retention effect, probably in the nervous tissue of the optic nerve, so that an occasional inadequate stimulus, such as a blow on the head or an electric current, would tend to take the same form. We may assume, then, that each set of sensory nerves carries impulses of one particular kind, for the simple reason that it is connected with certain receptors, and that these receptors are normally affected by only one class of stimuli.

The effect of stimulation when it reaches the brain center, and especially the cortex, is of peculiar interest to psychology, because it enables us to apply the method of self-observation to the receptive process. The central effect of stimulation,

[1] See p. 58.

observed in ourselves, is called a *sensation.* The mode of a sensation is related in a definite way to the mode of the stimulus.

Since no means have yet been devised for measuring the nerve impulse in the brain directly, we have to rely entirely on the results of self-observation. We observe and report our sensations, which correspond to the physiological processes in the brain.

Let m = the mode of stimulation, μ = the mode of nerve impulse at the center, and M = the mode (or quality) of the observed sensation. Then

$$\mu = \theta\ (m), \text{ or } M = \theta\ (m),$$

since M represents μ as it appears to the observer himself. In these equations θ is not necessarily a quantitative function, but signifies that m changes concomitantly with μ or M. For example, if m is a green light-wave, it produces a certain mode of effect in the brain center to which corresponds the sensation of green. If the stimulus be altered to a red light-wave, there is a corresponding change in the sensation. The human organism is capable of being affected by a great many different modes of stimuli. The qualitative differences of sensation to which these give rise will be discussed in chapters ix and x.

(*b*) Intensity: Experimental investigation within the past sixty years has brought to light some very definite mathematical relations between the intensity of stimulation and the intensity of the resulting impulse. These results have been obtained by measuring the intensity of stimuli in physical terms and comparing this with the central effect as reported by self-observation. Two stimuli differing in intensity are applied to the same receptor and the resulting sensations are observed and compared by the individual experimented upon. E. H. Weber, G. T. Fechner, and many later investigators applied this method to nearly every kind

of stimulus. It is found that the intensity of the stimulus and the intensity of the resulting central impulse (observed as sensation) are related generally according to the logarithmic function.

Let i = intensity of stimulus, ι = intensity of nerve impulse at the center, and I = intensity of sensation. Then

$$\iota = \phi\ (i), \text{ or } \mathrm{I} = \phi\ (i),$$

since $\mathrm{I} = \iota$ as it appears to the subject. But according to the experimental results, known as Weber's Law, ϕ represents the logarithmic function; so that the equation reduces to

$$\mathrm{I} = k \log.\ i,$$

where k denotes a constant which is the same for any given receptor, but differs for different kinds of receptors. For example, in hearing, the constant is $\frac{4}{3}$; that is, equal increases in *observed* intensities of sound occur when the stimuli increase in the ratio 1, $\frac{4}{3}$, $\frac{16}{9}$, $\frac{64}{27}$, etc.[1]

Rôle of the Receptor. — The process of stimulation and the nature of the sensory impulse depend quite as much upon the make-up of the receptor as upon the stimulus itself. The constitution of the receptor determines to some extent (1) the mode and (2) the intensity of the sensory impulse; (3) the metabolic condition of the receptor alters the intensity still further.

(1) The *mode* of the impulse and quality of sensation are determined by the process which goes on in the receptor. It is fruitless to speculate whether it would be possible to develop receptors which would enable us to see sounds or hear light. But within the range of a given receptor there are individual variations. The same light-wave stimulus which to one person appears green, to another looks yellow, to another gray. These differences are due to the constitution of the receptor; the first is called a 'normal eye,' the others are different types

[1] See ch. xii.

of color-blind eye (ch. ix). We receive the sensations red, green, bitter, sweet, etc., not only because each receptor is capable of being affected by certain stimuli, but because the physiological process set up in the receptor by each of these stimuli is of a certain definite mode.

Furthermore the efficacy of the stimulus is limited to the range of the receptor's capacity. Ultra-violet light-waves, for instance, produce no effect whatever in the rods or cones of the eye; sound waves and odor stimuli do not affect the eye though they do affect other receptors. The receptor does not start an impulse unless it is stimulated; but it determines whether or not a given stimulus shall work, and it also determines the precise mode of the impulse for such stimuli as do affect it.

(2) The make-up of the receptor is a factor in determining the *intensity* of the impulse also. A very feeble physical stimulus may produce no effect whatever in the receptor, and the actual intensity of any sensory impulse depends upon the intensity of the process set up in the receptor. Further, a receptor is affected only up to the limit of its capacity. If the physical stimulus is so intense that it exceeds the capacity of the receptor the sensory impulse is not increased beyond this limit. Very intense light blinds us, and intense sound vibrations destroy the ear-drum. The rate of increase of the impulse is also partly determined by the receptor. The constant k in the Weber formula varies for different types of receptor.

(3) The *metabolic condition* of the receptor varies from time to time, and this also alters the nature of the impulse. If a receptor becomes fatigued through constant use, its physiological efficiency is impaired. Thus the taste receptor becomes 'blunted' when the same sort of stimulus is applied repeatedly, so that a sweet substance no longer tastes so sweet.

In sight the fatigue factor appears to alter the mode of impulse as well as its intensity. When we look steadily at a

red spot for a long time and then turn the eye to a white surface, the part of the retina previously stimulated by the red now appears greenish instead of white. This, however, is really an intensity phenomenon; for the 'white retinal activity' is a compound process of which one component has been blunted by long-continued stimulation. In general, then, the metabolic condition of the receptor alters the intensity of the impulse as determined by the original stimulus. A katabolic state decreases the intensity of the impulse, while a highly anabolic state serves to increase it.

Rôle of the Sensory Neurons. — Finally, the effect of stimulation is dependent to some extent upon the state of the sensory neurons. The nature of the sensory impulse as determined by the stimulus and by the receptor may be altered before it reaches the center, either (*a*) by the retention effect in the nerves or (*b*) by the metabolic condition of the intermediate synapses. The retention trace of the neurons due to previous stimulation may alter the *mode* of the impulse, while the metabolic condition of the synapses may alter its *quantitative value*. Thus a 'familiar' color, taste, etc., is observed to have a slightly different quality from a new experience; this is due to the retention trace. A loud sound may not be observed at all if the communicating pathway is obstructed at the synapses; this occurs in conditions of 'inattention.' We shall examine these factors more closely later (ch. viii).

General Laws of Stimulation. — The various factors concerned in stimulation may be summed up in the following laws:

(1) The nature of the sensory impulse depends upon the nature of the *stimulus;* this involves two independent variables: (*a*) the mode of the impulse (and quality of sensation) depends primarily upon the mode of the stimulus; (*b*) the intensity of the impulse (and sensation) depends upon the intensity of the stimulus.

(2) The nature of the sensory impulse depends also upon

the *receptor*. The actual mode and intensity of an initial sensory impulse is determined by the nature and capacity of the receptor and by its metabolic condition at the time of stimulation.

(3) The character of the sensory impulse when it reaches the center depends also upon the *retention trace* in the intermediate neurons and upon the *metabolic condition* of the intermediate synapses. Retention alters the mode of the central impulse and the quality of sensation, while the metabolic state of the synapses affects the quantitative value of the central impulse.

2. Response

Nature of Response. — Every nerve impulse, unless dissipated by resistance along its pathway or transformed into potential energy, finally discharges through the motor segment of the arc into the effectors and produces physiological activity in these. The activity of the effectors, together with the grosser movements and other changes which result from this activity, is termed the *response*. It is so called because it is regarded as the creature's ' answer ' to the problem which the environment puts up to him through stimulation. Response is the motor effect of whatever sort brought about by nerve activity. It includes (*a*) muscular contraction and (*b*) glandular secretion, with all the bodily movements or transfer of substance within the body and all environmental changes which result from these processes.

a. Muscular Response. — Muscular activity is the most important type of response in man. Many separate neurons terminate in each muscle. Ordinarily the motor impulse affects all these separate neurons at once, with the result that energy is imparted to the entire muscle and it is thrown into a condition of physiological activity. This activity produces contraction of the muscular tissue, which causes it to shorten lengthwise and thicken in diameter. [See Fig. 20.]

The process of contraction is more speedy according as the intensity of excitation is greater. The duration of the state of contraction depends on the duration of the impulse. When the motor impulse ceases the muscle relaxes and returns to its original state.

The energy of the muscular response is very great compared with that of the nerve impulse which excites it. The nerve impulse serves merely to 'touch off' the activity in the muscle, somewhat as pulling the trigger of a rifle releases the energy stored in the cartridge.

Mode of Impulse. — The mode of the nerve impulse has no apparent effect on the character of the response. The only exception to this is (possibly) in the case of inhibitory motor impulses. There are some indications that the motor nerve is capable of transmitting a special type of nerve impulse which has the effect of checking or neutralizing the contraction of the muscle; but the nature of inhibitory impulses is at present uncertain. Most muscles occur in pairs, called antagonists, one of which serves to move the member in one direction, the other in the opposite direction; as when we bend and straighten the arm. The so-called inhibitory impulse is possibly only a shunting of the motor impulse from a given muscle to its antagonist.

While the mode of the nerve impulse has no effect in modifying muscular contraction, it does have an important bearing upon the type of response. The mode of the central nerve impulse probably determines to some extent which motor path out of all possible connections will be affected. If the central nerve impulse has a certain mode, it is able to permeate certain motor synapses; if it has a slightly different mode it passes into other motor paths. For example, when I recall some annoying occurrence the central process may start a motor impulse which results in my clenching the fist; whereas a similar thought, but with a different tinge, may result in scowling, kicking, or a flow of vituperative language. This

selection of motor paths probably depends upon the retention trace in certain motor nerves being similar to the mode of the present central nerve impulse. The path once determined, however, the mode of the impulse has no apparent effect on the muscular contraction.

Other Factors determining Response. — The final effect of the motor impulse depends also upon the *metabolic condition* of the motor synapses and of the muscular tissue. A muscle 'fatigued' through constant use of the same path contracts more slowly than one which is 'rested' and restored by anabolism.

The rate and amount of muscular contraction is also dependent upon the *amount of resistance* to the movement. If we lift a heavy weight the contraction proceeds more slowly or is more limited in extent than if we merely raise the arm itself. Normally, however, the rate of contraction is regulated by means of a secondary arc. When we begin a movement the kinesthetic receptors in the muscles report the state of contraction at every instant. If the arm muscles move freely their receptors are slightly stimulated; while if the muscular activity meets with resistance the kinesthetic stimulation is greater. This secondary stimulation results in a secondary motor impulse which supplements the original impulse and regulates the response. If we start to lift a heavy object which appears to be light, the initial motor impulse carries too little energy and the movement is not accomplished; but kinesthetic stimuli report the failure, and this secondary excitation starts a more intense motor impulse to the appropriate muscles. In the opposite case, the motor impulse may be 'toned down' by the secondary excitation.

The significance of the muscular type of response consists not in the muscular contraction as such, but in the bodily movements which it brings about. Responses include various movements of the arms and legs, head, trunk, face, vocal apparatus, etc. The combination of muscular activities which

result in any specific adjusted movement (such as rowing, walking, uttering a sentence) depends, however, far more upon the central coördinating activity than upon the motor discharge, so that we may leave this phrase of response for later discussion.

b. Glandular Response. — Glandular activity plays a far less important rôle in mental life than muscular activity; yet in many cases it forms an integral part of the response. Psychologists have only recently begun to appreciate the extent to which the glands are concerned in behavior.

Certain efferent paths terminate in the glands. When these ' motor ' neurons are excited by central activity the impulse energizes the glands and causes them to become active. This activity results in their secreting certain chemical compounds. For example, certain motor impulses affect our lachrymal glands and cause us to shed tears. The original stimulus may be either a bit of cinder in the eye, or a blow on the back, or a message announcing the death of a near friend.

One and the same sort of glandular activity may be combined with various modes of muscular activity in different responses. Weeping, for instance, may accompany ' rage ' movements as well as ' defense ' movements. Glandular activity which results in the secretion of saliva, urine, sweat, etc., forms part of the motor response when it is due to specific stimuli, but not when it is connected with the vital functions of nutrition and regulation. In the latter case it falls outside the limits of psychology.

General Laws of Response. — (1) The speed of muscular contraction depends primarily upon the intensity of the motor impulse.

(2) It depends also upon the metabolic condition of the motor synapses and upon the resistance of a weighted muscle.

(3) The motor impulse may be regulated by a secondary arc whose activity is stimulated by the kinesthetic receptors.

(4) Similarity between the mode of a central impulse and

the retention trace in the motor section of the arc may determine which path of several alternatives the motor impulse will take, but otherwise the mode of the motor impulse has no effect upon the type of response.

(5) Response includes the gross bodily movements which result from muscular activity as well as the muscular contraction itself; it includes also glandular activity so far as this is regulated by impulses from the cerebrospinal centers. Any change in the environment brought about by these muscular or glandular activities is part of the response.

(6) Coördinated responses, whether muscular, glandular, or mixed, depend upon the adjustive activity of the central part of the arc.

3. Adjustment (Integration and Coördination)

Nature of Adjustment. — The function of the central portion of the nervous arc is not merely to carry each separate sensory impulse over into a specific motor path. If this were its only rôle, the central system would scarcely deserve special notice; it would simply furnish certain additional links to the chain of sensory neurons, each of which receives the impulse from the preceding neuron and passes it on in turn to the next. In simple reflex arcs, like those concerned in sneezing and iris contraction, the central part of the arc actually does this: it merely transfers from the sensory to the motor path. Here the connecting neuron may be considered as part of the sensory segment, or as part of the motor segment. It has no special rôle of its own.

In all but the simplest arcs, however, the central neurons have several alternative connections. Some of these collect impulses from a number of separate sensory paths and combine them into one complex impulse; others distribute an impulse into several separate central and motor pathways, and thereby multiply its effects. Thus a response of the higher sort is usually not a simple outcome from a single stim-

ulus; a given stimulus may produce various kinds of response if its impulse reaches the higher centers. The central section in any ‘ higher ’ arc is connected with many sensory and many motor segments. It receives a ‘ system ’ of sensory impulses and sends out a ‘ system ’ of motor impulses. The combination (summation) of sensory impulses which occurs in the central part of the arc is called *integration*, and the capacity of the centers to distribute coöperating motor impulses is called *coördination*. Integration is illustrated in the perception of a book or other object as a single experience comprising various distinctive parts; coördination is illustrated by the simultaneous and successive muscular contractions which occur when we take hold of the book and lift it. The entire process is termed *adjustment*. It involves a complex, coördinated response to complex, integrated stimulation.

All the fundamental operations of nerve occur in the adjustive function of the central system. Summation is a prominent factor in integration, and distribution is the distinctive feature of coördination. Retention traces, variations in the metabolic condition of the central synapses, and modification, all affect the path of the impulse through the central region and assist in determining the process of adjustment.

Rôle of Retention and Modification. — The retention trace due to former impulses persists to a greater degree in the central neurons than in the sensory, since the sensory neurons are stimulated by impulses of many different modes. In the central system the neurons are apparently ‘ sorted out ’ somewhat according to the modes of their retention traces.

When any central neuron has received a certain mode of impulse it retains the effect of that mode. Thereafter it receives similar impulses more readily, and becomes less capable of receiving different impulses. If a somewhat dissimilar impulse reaches it, it may pass across the synapse and be modified by the retention trace, at the same time modifying the trace in that neuron. The extent of the modification depends

upon the intensity of the new impulse and the permanency of the trace.

If the new impulse is very intense it will be only slightly modified by the trace but will modify the trace very much. An illustration of this effect is observed when we first see a black swan. The perception is slightly modified by our previous experiences of white swans, while our general notion of *swan* (the result of many retention effects) is greatly modified by the new experience. If the new impulse is weak, the central impulse may be quite modified and conform to the mode of the retained trace, while the trace itself is not much altered. This occurs when the sight of a printed word suggests its auditory equivalent. If the new impulse is very similar to the trace left by former impulses, neither mode is much modified; as when we see a familiar scene.

On the motor side, central retention leads to the discharge of the impulse along the same paths as on previous occasions. This is illustrated by any well-formed habit, as when one writes his own name, or turns in at a familiar gate during a walk. The retention factor is the basis of all memorization and motor habits. It is owing to retention that every musician has his own peculiar 'touch,' that each of us pronounces words in his own way, etc.

Rôle of Metabolic Condition. — The metabolic condition of the central synapses affects the *intensity* of the incoming impulse. (The retention trace affects the *mode*.) The effect of metabolic variation is observed in the 'unevenness' which characterizes perception. Certain features of an object are prominent, other details are in the "margin of consciousness." The "fluctuation of attention" is another instance of sensory change due to central metabolism.

On the motor side, the metabolic condition determines to some extent which of two alternative motor paths shall receive the outgoing impulse. If one pathway has been in constant use, its synaptic connections become 'fatigued' and for a

time offer greater resistance to the passage of impulses; as a result the impulse passes out over some other synapse which offers less resistance, and is thereby shunted into another path. This is illustrated by the normal variations of our motor activities; we frequently shift from one kind of work to another.

Laws of Adjustment. — Our results so far may be summed up in the following laws:

(1) The simplest operation of the central part of the arc is to convey a nerve impulse from a sensory path to a motor path (*conduction*).

(2) The higher central neurons serve to *integrate* several sensory impulses into one complex impulse; this is accomplished by means of their collateral branches; it involves the *summation* of impulses.

(3) The higher central neurons also *coördinate* motor impulses by sending out several coöperating impulses at once. This involves the *distribution* of an impulse through several branches.

(4) The central activity depends not merely upon the mode and intensity of the impulses which it receives, but also upon the *retention* trace left by previous impulses in the central neurons themselves, and upon the *metabolic condition* of the central synapses. Retention alters the mode of the received impulse, metabolic conditions alter its intensity. Both are factors in determining the path of motor discharge.

Significance of the Central System. — The more closely the workings of the nervous mechanism are examined, the more evident does it become that the central section of the arc is its most essential part. It is by means of central processes that we receive and 'grasp' as a whole a complex situation which confronts us in the environment; and it is by means of these same processes that our movements, instead of being detached reflexes, become adapted responses 'appropriate' to the total situation. Whether we shall reach out and catch

an approaching ball, or shall dodge it, depends upon the integrative action of the central system; and the complex group of muscular contractions which we perform in either case are determined by the coördinating action of the same system.

We should not undervalue the sensory and motor functions. The central system acts upon the sensory data which it receives; its efficacy is due in large measure to the complexity of the stimuli and to the differentiation of the receptors. And since the centrally adjusted impulse acts through the motor paths and effector organs, the suitability of the response depends upon the presence of numerous muscles advantageously placed and in good working order. Granting all this, we must still recognize that the central system is the prime factor in adjusting the response to the situation.

So remarkable are the fine adjustments which the central system carries out, that many investigators refuse to believe that the brain as a mere nerve mechanism is capable of performing them. Thus we have the 'interaction' theory of adjustment, which holds that the receptive data are handed over to a mental personality which is distinct from the brain — which 'intuits' the situation and 'decides' upon a course of action, and then energizes the appropriate motor centers. While this view is quite tenable, it offers difficulties of its own, and in fact only removes the explanation from processes with which we are more or less familiar and carries it further into the realm of the unknown.[1]

Methods of Investigating Adjustment. — The real problem in explaining the process of adjustment is to show how the integration and coördination which we observe in organisms is *actually brought about*, and how it happens that the total response is *appropriate* to the stimulus-situation.

No means have as yet been devised for observing the operation of nerve activity in the living brain; and if the central

[1] See Appendix, "Subjective and Objective Phenomena," p. 413; "Conscious Purpose," p. 427.

neurons are removed from their organic connections the whole process of integration and coördination disappears. In the present state of science the operation of adjustment can be studied only indirectly.

Some light is thrown on the process by the study of *brain structure,* which enables us to trace the course of bundles of fibers from one part of the brain to another. These findings indicate what centers are actually connected. Another means of study, somewhat similar to this, is the so-called method of *degeneration.* If a given area in the brain be cut out or destroyed, the course of degeneration of nerve tissue follows certain paths. Such degenerations often occur in disease, and many such cases have been studied in the human brain. The animal brain is also studied by experimental excision of brain centers; but the brains of all subhuman animals are so much simpler than the human that this method leaves much to be desired.

Another indirect means of studying adjustment is through *artificial stimulation* of various parts of the brain by an electric current. Experiments so far made by this method appear to show that the stimulation results in one movement or another according to the region stimulated.

All these methods have advanced our knowledge of the adjustment process considerably. But they serve only to indicate certain *paths* of central conduction. They do not account for the complexity of 'integration' and 'coördination' as found in actual mental life. And this is after all our fundamental problem.

Two methods have been used in investigating this and other problems of psychology. (1) The study of *behavior.* This consists in working at the *two ends* of the nervous arc. Stimuli are applied to the various receptors and the motor effect is noted. The stimuli may be given artificially. The animal or human being is placed under carefully prepared conditions, a measured stimulus is applied, and the resulting motor effects

are measured. Or we may observe how the animal or human acts under natural conditions, noting the stimuli which affect him and the nature of his responses. (2) The study of *conscious experience* through self-observation. Here we are working at the *central portion* of the arc, observing how the stimuli affect our own brain and the various stages of the central process culminating finally in the motor impulse.

We shall examine the operations of mental life as indicated by the behavior method in the next two chapters, and then pass to the study of conscious experiences.

Collateral Reading:

Dewey, J., The Reflex Arc Concept in Psychology, *Psychol. Rev.*, 1896, 3, 357–370.
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Donaldson, H. H., Growth of the Brain, chs. 13–16.
Titchener, E. B., Experimental Psychology, Vol. II, Part II, secs. 1–6.
Fechner, G. T., Elemente der Psychophysik.
Sherrington, C. S., Integrative Action of the Nervous System, chs. 1–8.
McKendrick, J. G., Principles of Physiology, ch. 7.

Practical Exercises:

Study (*a*) several cases in which you can readily perform two independent actions at once, and (*b*) several in which one act interferes with the other. Determine if possible a criterion for the 'coöperation' and 'interference.'

Observe a child learning to use knife and fork; compare with your own movements in the same act; note and report differences in precision of the coördination.

Test Weber's Law for lifted weights. Take 50 similar envelopes; weight each with shot, so that each is 5 grams (or $\frac{1}{4}$ ounce) heavier than the preceding. Lift No. 1 (10 grams) and then No. 2 (next heavier), giving judgment of "equal weight" or "second heavier." Lift No. 1 and then No. 3, giving judgment. In same way compare Nos. 4, 5, etc., successively with No. 1 as standard, till difference is just noticeable. Repeat the experiment with No. 11 as standard, comparing it with Nos. 12, 13, etc. Repeat with other standards (21, 31, 41), recording all the results. Determine the ratio between *standard weight* and *just noticeably heavier weight* in each case. How do these ratios compare with one another?

CHAPTER VI

BEHAVIOR

Operation of the Nervous Arc; Adaptive Reaction. — In the two preceding chapters we have considered the special properties of nerve which render its activity different from other types of cell, and the typical functions of the three segments of the nervous arc. But neither the characteristics of nerve nor the performances of the separate parts of the arc describe in any adequate way the activity of the nervous system when it operates as a whole.

The neuro-terminal system is the mediator between the creature and his environment.[1] Organisms which are provided with a nervous system react in a specific way to the forces exerted upon them from outside. They are not affected like a billiard ball struck by a cue, or like a coin when it receives the impress of a dye. The forces which act upon the nervous system as stimuli lead to responsive activity on the part of the organism. Organic reaction is something different from the physical conception of reaction to an external force. The organism 'strikes back' at the environment.

We are not to interpret this striking back in an anthropomorphic sense; it does not necessarily imply intelligence, consciousness, or deliberation.[2] It means simply that the organism modifies the environment and that the give-and-take process is somewhat different from ordinary physical action and reaction. The reactive response of the organism to stimulation is *adaptive;* and by this we mean that it tends to protect the organism from injury and to promote its life processes.

Take the illustration used in chapter i. When we are out

[1] See Appendix, "Thought-Transference, " p. 418.
[2] See Appendix, "Personification of Natural Phenomena," p. 433.

in a gale and a gust of wind blows suddenly against us, if it is not so strong and sudden as to blow us over we brace ourselves against it. This is a typical example of organic response. The reaction is responsive only when the pressure acts as a stimulus and there is time for adjustment of our motor apparatus. The phenomenon of being ' blown over ' is not a responsive reaction, but a physical reaction; the wind acts upon our body as it might upon a vase, and we topple over. In highly organized creatures the adjustive activity mediated by the nervous system serves in most cases to prevent this result, which might prove disastrous to the creature's existence as a living being.

Again, when you are seated at a dinner table your receptors are stimulated by the sight and smell of food. Your reactive response is a series of complicated movements which convey the food to your mouth and lead to its digestion. Taken by itself, the action of light waves upon the retina or of odorous particles on the olfactory receptors is not very forceful. But these stimuli bring about a response in the form of coördinated muscular contractions and adaptive movements which serve to maintain your existence as a living organism. *Responsive reactions*, of which these are merely examples, *tend in general to promote the life processes or prevent the destruction of the creature.* This is the distinctive characteristic of the operation of the complete neuro-terminal arc.

This does not mean that every single response is helpful to the creature. In trying to brace myself against the wind I may actually fall forward and receive greater injury; or in eating I may inadvertently introduce poison into my system. The notion of adaptiveness means simply that the response tends to be suitable to the stimulus in all ordinary situations. This is accounted for by the fact that unsuitable forms of response are more likely to cause a creature's destruction, and hence we assume that they are gradually weeded out in the course of many generations. In other words, the *adaptiveness* of response appears to rest upon *natural selec-*

tion: the fittest individual and the most suitable reaction survive in the long run.

Concept of Behavior. — The specific type of activity mediated by the neuro-terminal system in the manner just described is called *behavior*. Organic behavior consists of such activities of living creatures as are manifested in muscular contraction and glandular secretion (or some equivalent processes in lower organisms) together with the various resulting movements and physiological changes. The movements of a creature are not behavior unless they are mediated by activity of the nervous arc. When a man is struck down by a blow, or when he is rolled over during sleep, his falling or rolling movements are not behavior. Neither are growth or the healing of a wound included under the term. Behavior movements are such as are brought about by motor nerve impulses; and the latter always result from stimulation. Hence, behavior is to be regarded not merely as bodily movement or motor activity, but as the adjusted responsive effect of stimulation. It involves the operation of the entire neuro-terminal arc.

Types of Behavior. — We might class behavior according to the different kinds of relationship which it brings about between the organism and the outer world. This would give such general types of behavior as feeding, defensive, aggressive, mating, parental, filial, general social, locomotor, and the like. But this division depends upon a rather high stage of nervous and mental evolution. Running away, raising our arms and hands, clenching the fist, and fear-expression all belong under defensive behavior. Yet psychologically these actions belong to very different types. In determining the response and adapting it to the situation the central nervous system is the important factor. The mode of central activity in running away is quite different from what it is in coming to guard, and our analysis of behavior is confused if we class both of these types under the same heading.

The difficulty is avoided in a classification based upon the

nature of the central adjustment. On this basis human behavior includes three main types: *reflex action* (simple response), *instinctive behavior*, and individually modified *intelligent behavior*. They are commonly called *reflexes*, *instincts*, and *intelligence*. The protozoa, or one-celled animals, which lack a specialized nervous system, have no reflexes properly speaking. But they exhibit a very similar form of simple response called *tropism*. In these species and among lower metazoa there are several gradations between simple response and instinct. In certain species of protozoa, such as paramecium, the swimming activity consists in a combination of similar movements made by a set of cilia; this may be called a compound response. A similar compounding of responses occurs also in higher animals, and constitutes a grade of behavior intermediate between reflexes and instincts.

In man intelligent behavior becomes differentiated into two distinct types, called *habit* and *rational behavior*. Habits consist of comparatively fixed modes of action, which after they are established resemble closely actions of the instinctive type; they constitute the lowest stage of intelligent behavior. Rational actions are more variable, and belong to a higher level.

Intelligent behavior in man develops also two 'social' types, *communication* and *conduct*, which are concerned with the relations between a man and his fellows. These varieties of intelligence together with reflex and instinctive behavior make up the general classes of mental functions mentioned in chapter ii.

1. Reflex Behavior

Reflex Action. — The *reflex* is the original form of behavior among creatures possessing a nervous system. It involves the operation of a single nervous arc or a number of such arcs acting together simultaneously. Reflexes are either *simple* or

compound, and they are distinguished as lower or higher according as they involve only a lower arc or higher coördinating centers. Usually the simple reflexes are lower and the compound higher.

Simple Reflexes. — Simple reflex action is brought about by the operation of a simple nervous arc. In reflexes of the simplest and lowest type, the sensory nerve impulse passes to a sensory center, thence directly to a motor center, and so by a motor path to the muscle or gland. [Fig. 24; cf. Fig. 3 A.]

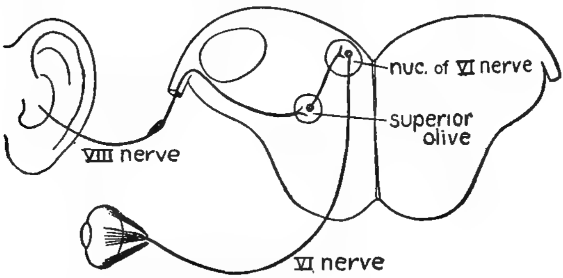

FIG. 24. — SIMPLE REFLEX

Diagram of simple auditory reflex. The auditory stimulus starts an impulse through the VIII cranial nerve; in this reflex the impulse is conducted by an intercalary neuron to the origin of the VI nerve, and along this nerve to the external rectus muscle of the eyeball, producing a movement of the eye toward the side. [From Herrick.]

In higher reflexes the impulse passes from the first sensory center to another (higher) sensory center before passing over to the motor tract. Sensory and motor centers which lie nearest to the receptor or effector organs are called *primary* centers, those next further from the periphery are called *secondary* centers, etc. The lower reflexes pass only through the primary centers. In the case of spinal reflexes these primary centers lie in the spinal cord near the place where the nerves enter. In the cerebral reflexes the primary centers lie at the base of the brain. The knee-jerk is a typical example

of spinal reflex;[1] winking is a typical cerebral reflex. Sneezing is another typical reflex, and so is coughing where it occurs 'involuntarily.' The elaborated cough, like the artificial wink, is not a pure reflex. Usually the response in a simple reflex is a movement on the *same* side of the body as the stimulus.

Besides the simple reflexes belonging to the lower levels, there are relatively simple responses which involve higher or secondary centers. A sudden loud noise often produces violent beating of the heart. The sensory impulse in this case goes to a higher center, and thence passes out through a motor pathway connected with the cardiac muscles.

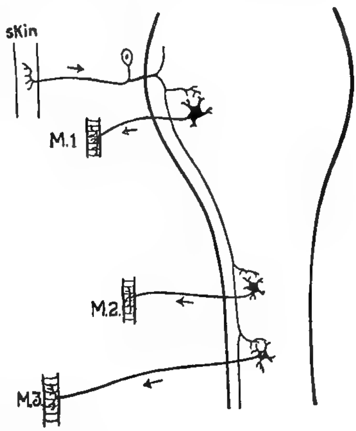

FIG. 25. — DISTRIBUTED REFLEX

Stimulation of a receptor in the skin leads to contraction of several different muscles M1, M2, M3. [From Herrick.]

Compound Reflexes. — Compound reflexes are those in which two or more sensory impulses are combined, or in which a single sensory impulse finds multiple expression. [Fig. 25.] They nearly always involve higher centers, though in some cases part of the reflex uses only a simple arc. Thus the knee-jerk may form part of a compound reflex; a portion of the impulse may pass over directly from the primary sensory center to the motor path and cause the leg to fly up, while part may travel to a higher center and lead to some other type of activity.

If the entire impulse reaches a higher center it may result in a coördinated compound reflex. Grasping, sucking, and

[1] It should be said, however, that many physiologists do not regard the knee-jerk as a true reflex.

certain vocal reflexes are examples of this. In the grasping reflex of the hand all the fingers are flexed at once; the sucking reflex involves coördinated stimulation of several muscles in the lips and tongue. Where higher centers are involved the response may be on the opposite side of the body from the stimulus; frequently it is bilateral. This is due to the fact that the nerves cross to the opposite side of the cord or brain, and that the pathways to and from the two sides of the body are connected at the secondary centers.

In reflex action there is usually a certain compounding of impulses from the sensory segment of the arc. The eye-wink is generally a response to stimulation of the whole field of vision, or at least a large area; the reflex of withdrawing the hand is usually in response to an impact or temperature stimulus which affects many receptors covering a noticeably large area. The compounding of sensory impulses is not so significant as the motor complication; it serves to intensify the effect rather than to complicate the forms of manifestation.

In the compounding of reflexes the effect differs according to the nature of the component motor impulses. Thus we may distinguish between *antagonistic* reflexes, in which the impulses lead to opposing or antagonistic muscles, and *allied* reflexes, where the separate impulses tend to reinforce one another. In certain cases the impulses tend partly to neutralize, partly to reinforce one another; these are called *allied and antagonistic.* Where several reflexes follow in succession, they may be *alternating* (e.g., in walking), or *supplementary* (e.g., the flexing of fingers at each joint in grasping). Where a completed reflex causes a new stimulation leading to another reflex, the series is called a *chain* reflex. [Fig. 26.] This is the border-line between reflex and instinctive activity.

One further complication of the reflex deserves notice. When two separate stimuli, one of which produces a marked reflex while the second does not, have frequently occurred in

conjunction, it may come to pass in the course of time that the impulse due to the second stimulus will discharge into the motor path of the first and produce the response which originally belonged to the first. If a bell be struck every time that the knee-jerk is stimulated, after a while the sound of the bell will call forth the knee-reflex response even when the knee is

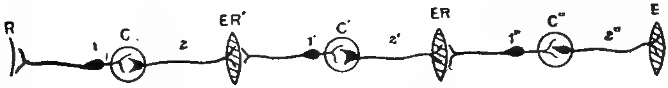

FIG. 26. — CHAIN REFLEX

Stimulation of receptor R produces contraction of effector E, which stimulates receptor R′, producing contraction of E′, etc. C, C′ = centers. [From Herrick.]

not touched. This modified activity is called a *conditioned* reflex. It is of considerable importance in intelligent behavior.

Nature of the Reflex. — The distinctive characteristic of the ‘ pure ’ reflex is that the neural paths which constitute its arc are definite and the resulting response very precise — the motor outgo is not diffuse. Hence, the form of response depends almost wholly upon the nature of the present stimulus, and not upon the retention effect of preceding impulses which have affected the same arc. This characteristic is modified in conditioned reflexes.

The relation between stimulus and response in reflex action may be stated as follows: (1) The response usually varies with the *intensity* of the stimulus. A very intense stimulation generally causes violent contraction. It may also cause a more wide-spread effect. Thus the shudder reflex extends over a larger part of the body when the stimulus which excites it is more intense.

(2) The nature of the response depends somewhat upon the *mode* of stimulation. The stimulus known as tickling is less intense than ordinary touch stimulation, but owing to its peculiar quality it causes a much more violent response than simple contact. We are familiar with the peculiar effect of

red on the behavior of bulls and other animals; here the ' red ' quality (mode) of visual stimulation determines the specific form of response.

(3) The response varies considerably with the *metabolic condition* of the organism. When certain motor end-synapses have been fatigued through frequent stimulations of the same sort, the response tends to become less and less intense. This fatigue effect is only temporary; after a period of rest the intensity of response is restored.

(4) In pure reflexes the *retention* effect is negligible, but it plays an important rôle in conditioned reflexes.

Reflex action is the fundamental type of behavior. The higher types arise out of it through various complications. Instinct and intelligence may both be regarded as consisting of the operation of chains of reflex arcs. The chief difference between these two types lies in the fact that the neural connections which determine the pathways and mark out the arcs are *inherited* in the case of instinctive behavior, while in intelligent behavior the connections are formed and perfected (or modified)through the creature's individual *experience*.

Human Reflexes. — In the human adult comparatively few activities belong to the pure reflex type. For the most part our motor impulses are modified by complex central impulses which involve a number of higher arcs. Even such a simple reflex as winking may be reinforced or partly inhibited by central control; and the same motor paths which carry impulses for the winking reflex also conduct impulses for ' voluntary ' winking and for closing the eye.

Table III gives the most prominent and important human reflexes. In some cases several allied reflexes are grouped under a single head. The autonomic processes (circulation, breathing, etc.) may be regarded as a continuous succession of reflexes. Since these activities possess no psychological interest they are not included in the table.

Table III. — Human Reflexes

A. Purest — least subject to central modification in adult

'Pupillary' or iris reflex
Ear twitching (controlled in some individuals)
Hand withdrawal (to heat and pain)
Myenteric reflexes (operation of stomach and intestinal muscles in digestion)
Snoring
Shuddering
Starting (to sudden noise, etc.)
Trembling
Shivering
Rhythmic contractions (in epilepsy, paralysis agitans, etc.)

B. Largely pure — subject to inhibition or reinforcement

Winking
Accommodation, ciliary reflex
Eye-fixation and convergence
Hiccoughing
Sneezing
Patellar reflex (knee-jerk)
Dizziness reflexes
Yawning
Vomiting
Facial reflexes (to bitter taste, etc.)
Salivation
Tickle reflexes
Hand twitching (to dermal pain)
Plantar reflex (to stimulus on sole of foot)
Great toe reflex
Vasomotor changes (blushing, paling)
Breathing changes (to specific stimuli and to onset of sleep)
Sudorific reflexes
Groaning
Laughing
Cramp movements
Squirming

C. Occasionally pure, more often centrally modified

Coughing
Swallowing and gulping
Visceral discharge, etc.
Functioning of sex organs
Reflexes to odors
Gasping
Weeping
Sobbing
Smiling
Wincing, etc.
Scowling
Stretching
Convulsive contractions (to deep pressure and heat, to pricking and other dermal pains, and to visceral pain)

D. Pure in infancy, centrally modified in adult

Sucking
Biting and grinding
Spitting
Hunger and thirst reflexes
Lip and tongue reflexes
Vocal reflexes
Turning the head
Tossing
Grasping (finger reflexes)
Tugging (wrist reflexes)
Clasping (elbow reflexes)
Reaching (shoulder reflexes)
Kicking (knee reflexes)
Stepping (gluteal reflexes)
Jumping (ankle reflexes)
Sitting up
Bending forward
Rising

E. Posture reflexes

Holding head erect
Sitting
Standing
Equilibration

2. Instinctive Behavior

Relation of Instinct to the Reflex. — The term *instinct* has been variously defined. Earlier writers treated it as a mysterious innate power possessed by subhuman animals, which enabled them to do the right thing in the right way, without consciousness or deliberation. To-day we know that instinctive activity is the result of integration and coördination of nerve impulses, and that the adjustment is due to inherited connections between sensory and motor neurons. Even among reflexes we find a certain degree of complexity. There is no sharp dividing line between compound reflexes and the simpler instincts.

The term *instinct* will be used here (following many recent writers) to denote those complications of behavior which involve a series of reflex activities, where (*a*) one reflex furnishes the stimulus that leads to the next, and (*b*) the connections depend upon inherited structure, not upon individual modifications. In walking, for example, each step serves as a stimulus for the next. When the left foot touches the ground the tactile stimulus, acting in conjunction with the muscular stimulus in the muscles of the left leg, starts the motor impulse for lifting the right leg, and so on.

In most instincts each reflex in the series involves a different kind of reflex from the preceding. A typical example is the suckling instinct in the human infant. This involves several different reflexes. The first is the bending movement of the child toward the breast, a reflex which may be stimulated by hunger or by sight or odor. Next is the grasping reflex with the lips; then follows the sucking reflex and finally the swallowing reflex. Each reflex action in this series furnishes a stimulus which leads to the succeeding reflex. The grasping movement of the lips is stimulated by the touch of the lips; the sucking movement by the grasping sensation, and swallowing by the action of the milk upon the tongue, lining of

the mouth, and glottis. This succession of response and stimulation is characteristic of instinctive behavior generally.

A reflex arc is made up of a certain series of neurons or neuron groups joined into a circuit. Reflex action takes place because the pathway so formed constitutes the line of least resistance for the discharge of nerve energy. In the same way an instinctive circuit-system is made up of several superimposed reflex arcs. Instinctive action takes place because each reflex which composes it is a path of least resistance, and because the motor response of one reflex provides the appropriate stimulus for the next.

If when the infant bends forward to seek the breast the lip contact is prevented, the lip-grasping reflex is inhibited and for the time being the instinct is not completed. The development of an instinct may be thwarted if at any stage the movement does not lead to the proper stimulus for the next stage. As a general rule, however, the same fundamental instincts appear in every individual at about the same period of life. This is because we all inherit the same fundamental nerve structure and live in substantially the same environment.

Evolution of Instinct. — Each species of animal, mankind among the rest, has evolved certain typical kinds of instinctive behavior. Some types of instinct belong to a wide group of species; others to a single species. The origin of widespread instincts as well as specific varieties may be explained on the basis of natural selection, as follows: Each separate reflex appeared in the first place in connection with some chance variation of nerve structure; the variation was selected and has survived because it is suited to the needs of the creature. The grouping of reflexes into instincts is also the result of structural variations due to chance, which have survived on account of their utility. If a new combination of reflex paths, brought about by a chance variation in growth, prove especially fitted to preserve the animal's life, it has a

greater chance of surviving and being transmitted to posterity.

The combination of reflexes into coördinated instincts is due to the growth of the fibers of their constituent neurons in certain directions. If the motor neurons of one arc grow in such a way that their effectors coöperate with the receptors and sensory neurons of another arc, the two may act together and bring about instinctive activity. But not all such combinations are advantageous. In the suckling instinct of the human infant, for example, the combination of activities whereby the act of grasping with the lips stimulates directly a sucking reflex, is a distinct advantage to the child. If a variation should occur whereby the lip-grasping reflex results in stimulating some entirely different movement, the combination might be distinctly disadvantageous and lead to the child's untimely death. Some of our fundamental instincts, such as rage and fear, were presumably of advantage originally to their possessors. The resulting movements of aggression or defense served to ward off threatening danger. These instincts are no longer advantageous to civilized man; but instead of being weeded out by natural selection they are suppressed individually by intelligent inhibition.

Classes of Human Instincts. — The human adult seldom behaves in a purely instinctive manner. His activities are largely modified and controlled by individual experiences; they belong for the most part to the intelligent type. Even the basal instincts are partly suppressed and reduced to conventional forms. There are two modes of behavior in man which take the place of pure instincts: *modified instincts* and *instinctive tendencies*.

Modified instincts include the partly inhibited expressions of anger, fear, and the like; also partly trained activities, such as walking, feeding, parental and sexual instincts, expression of sorrow and delight. In all such cases the instinctive mechanism is a fundamental feature; but individual experience, es-

pecially the social example of our fellow men, leads to radical changes in the form of behavior.

There have been wide differences of opinion among psychologists as to the number of human instincts. James and others insist that man possesses a great variety of instincts — as many, in fact, as any of the lower species. Other writers restrict human instincts to a few kinds. Both views are partly correct. Few *pure* instincts are found in the human adult, but a great number of *modified* instincts. It would not be proper to treat these as forms of intelligent behavior, yet strictly speaking they are not true instincts.

It is difficult to classify human instincts on the basis of their origin, because some arise from a combination of several different factors. To a certain extent we may divide them according to the specific vital function [1] which they promote. But this does not carry us far, for growth, repair, and regulation are not promoted by any specific instincts, except (indirectly) by those which are also concerned in nutrition. The (*a*) *nutritive* and (*b*) *reproductive* functions each form the basis of certain deep-rooted instincts. The active relations between man and his environment give rise to two further varieties which are termed (*c*) *defensive* and (*d*) *aggressive* instincts. Biological organization as such is not associated with instinctive behavior, but the organization of individuals into groups is promoted by certain (*e*) *social* instincts.

Table IV gives the chief kinds of instincts in each of these five groups. The filial instincts of infants do not properly belong among adult instincts, but are inserted because of their close relation to the maternal instincts. Primitive forms of certain types are given in brackets.

Metabolic expression includes a variety of complex manifestations of general bodily or 'systemic' conditions (joy, sorrow, etc.) Some of the defensive and aggressive instincts are usually social in their manifestations. The instincts of subjection

[1] See ch. ii.

TABLE IV. — HUMAN INSTINCTS

1. *Nutritive*
   Metabolic expressions
   Walking
   Feeding
   Wandering [Hunting]
   Acquiring [Hoarding]
   Cleanliness

2. *Reproductive*
   Mating (sexual attraction, courtship)
   Maternal
   Filial (of infancy)

3. *Defensive*
   Flight
   Subjection
   Hiding
   Avoiding
   Modesty [Shyness]
   Clothing [Covering]
   Constructing [Home-making]

4. *Aggressive*
   Fighting
   Resenting
   Domineering
   Rivalry

5. *Social Organization*
   Family (parental and filial)
   Tribal [Gregarious]
   'Apopathetic'
   Sympathetic
   Antipathetic
   Coöperative

and rivalry generally involve social relations between man and man; the domineering instinct may have as object either human beings or lower animals.

The family instincts have apparently a different origin from the gregarious and other types which follow in the list. Parental and filial instincts are based essentially upon sex relations, while the tribal instincts are due to stimuli which are only remotely traceable to the reproductive life. In some human races the general social stimuli are weak, and tribal association is lacking; but family life may exist without community life.

The instincts termed ' apopathetic ' (for want of a better name) are responses to the attitudes of others. Thorndike

notices a variety of types: (1) We act in certain ways when others are present, even though they are not concerned with our doings. (2) We respond differently when they enter into communication and relation with us. (3) We respond in specific ways to the approval of others, and (4) to their scorn.

Instinctive Tendencies. — An *instinctive tendency* is a mode of behavior comprising many distinct sorts of action, all of which are individually learned, but which resemble one another in general type; the 'type' itself is not learned but belongs to the constitution of the species.

Table V gives a list of instinctive tendencies belonging to the human species. The most fundamental types are *imitativeness*, *playfulness*, and *curiosity*.

TABLE V. — INSTINCTIVE TENDENCIES OF MAN

Imitativeness
Playfulness
Curiosity
Dextrality (right-handedness)
Esthetic expression
Communicativeness

The relation between inherited and acquired factors in instinctive tendencies is best illustrated in the case of *imitation*. Every imitative act is individually acquired; but there are distinct inherited paths of nervous connection which facilitate certain kinds of response that reproduce ('imitate') the movements of other beings. To illustrate from other species, the parrot is able to imitate many modes of vocal expression, and the monkey is able in the same way to imitate gestures. But the parrot has no mechanism for reproducing gestures, nor the monkey for reproducing articulate expression.

In the human child and adult the underlying instinctive tendency to imitate includes not only vocal expression and gesture, but muscular movements of almost every sort. The specific acts which we perform when we imitate are learned, but the direction taken by the learning process is based upon

an inherited tendency in the nervous make-up of man. In the same way *curiosity* manifests itself in different ways according to the individual — in exploration, study of nature, listening to gossip, etc.

Play is partly an imitative phenomenon. Many children's games are due to imitation of the serious activities of adult life. Learning any specific game may be an imitative act. But the play-instinct has a distinctive character of its own; play means a tendency to perform acts which are not directly concerned with one's mental and vital welfare. This is characteristic of all play, whether imitative or spontaneous, social or solitary. Such widely different activities as 'playing telephone,' a game of foot-ball, a solitary game of cards, a ramble in the woods, have one common feature: they represent relaxation from the serious business of life.

Right-handedness, more properly called *dextrality*,[1] is the preference of one hand or the other in performing manual acts; in a majority of cases the right hand is preferred (dextro-dextrality), though in many individuals the left is dominant (sinistro-dextrality). The tendency is supposed to rest upon a greater development of certain motor centers in one cerebral hemisphere, and is probably connected with the formation of the speech center, which is usually found in the left side of the brain. (The left hemisphere controls the right side of the body and vice versa.)

Esthetic expression, the 'artistic touch' which many human acts exhibit, has not as yet received any satisfactory explanation. The tendency to *communicate* manifests itself in many ways, such as gesture, speech, etc. which are developed systematically by intelligence. Certain acts classed among the instincts may also be regarded as instinctive tendencies. Chief among these are acquisitiveness, constructiveness, companionship (tribal instinct), and mastery (domineering instinct).

[1] *Psychol. Bull.*, 1909, 6, p. 131. The term *ambidextral* is preferable to *ambidextrous*.

Development and Variability of Instincts. — Instincts and instinctive tendencies, like reflexes, are inherited. They belong to the original inborn constitution of each individual. The nerve structure through which they operate is provided for in the original germ cell from which the individual grows, and is derived directly from one parent or both. This does not mean that a given instinct is present at birth or that the appropriate neural connections are already formed at birth. In most cases the structural basis for the instinct is 'practically ready' at birth and in some cases long before birth; but the manifestation of the instinct depends upon the first stimulation, which may occur at some later period of life.

In certain instincts the welding of the chain of stimuli is not completed till a considerable time after birth. Human walking, for example, is usually not completely adjusted till some time in the second year of postnatal life. The reproductive functions reach their full development only at sexual maturity, usually between the tenth and fifteenth years.

In short, any given instinct begins to manifest itself at a certain period of life, and the period at which it appears depends not so much upon the chance occurrence of appropriate stimuli, as upon the perfection of the nerve mechanism. If the proper stimuli do not occur at the right season, the appearance of the instinct is delayed, and in special cases it may never be perfected. It should be remembered that the evolution of any instinct depends upon the general conditions of life in the species which has perfected it, and especially upon the presence of a definite type of environment in which all its members live; hence only in rare cases would the appropriate stimulus for a basal instinct be lacking.

Even a pure instinct is not invariable. Its form of expression depends primarily upon the nature of the initial stimulus in the chain, but it is modified by the influence of other stimuli which occur as the act is being performed. The rapidity, force, and motor manifestations of the suckling instinct vary

considerably with the infant's sense of hunger. In the adult, the effect of accompanying stimuli is readily noticed in the act of walking. We adjust our locomotor movements in different ways when we step up or down, walk on a slope, avoid a stone in the path, etc. Some of these modifications result from differences of pressure on the sole of the foot, others are due to visual stimuli from objects ahead. Nor is this altogether a matter of 'consciousness.' We adjust our walking movements to slopes and obstacles quite as well when engaged in conversation as when we are paying strict attention to the path in front. We step down from the curb or walk around a tree often without being aware that we are doing so.

These motor adaptations are due to variations and different combinations of stimuli. The chief difference between the variations which occur in instinctive and intelligent behavior is that instinctive modes of expression are not altered by past experience, while intelligent expression depends essentially upon the effects of retention.

If instinctive expression is not modified by experience, how is it that walking and other instincts show the effect of learning? The explanation is that in such cases certain inherited paths or lines of neural conduction are broken up and other pathways are substituted. To the extent that this occurs the behavior loses its instinctive character. In the complex cortex of the human brain the higher centers gather in and send out impulses which inhibit certain reflexes and reinforce others. The effect of this is to transform the response little by little from the instinctive to the intelligent type. The modified instincts lie midway between these two types. Our adjustments in walking are due to past experiences of stepping up or down and avoiding obstacles; but the general coördination of locomotor activity is instinctive.

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Loeb, J., Mechanistic Concept of Life, ch. 3 (secs. 1–3).
Loeb, J., Comparative Physiology of the Brain and Comparative Psychology, ch. 13.
Driesch, H., Science and Philosophy of the Organism, Vol. II, Part III, ch. 2.
Woodworth, R. S., Dynamic Psychology, ch. 3.

PRACTICAL EXERCISES:

Report all noticeable right or left preferences in your actions; e.g., which arm or leg acts first in putting on or removing your garments.

Analyze the processes included in three different human instincts, e.g., eating, walking, defensive behavior.

Examine why you have the following tendencies: (*a*) to sympathize with friends; (*b*) to collect objects of some kind; (*c*) to find out things you do not know.

CHAPTER VII

BEHAVIOR (*continued*)

3. Intelligent Behavior

Nature and Neural Basis of Intelligence. — If similar stimuli be applied to the same individual repeatedly, the responses which follow may differ from time to time. This variability, which characterizes certain kinds of activity, especially in the higher vertebrates, does not throw doubt upon the uniformity of nature; it means simply that conditions *within* the organism have altered. There are two distinct types of individual modifications in behavior, due to *fatigue* and *adaptation*, respectively.

(*a*) The *fatigue* effect occurs in instinctive actions and reflexes as well as in intelligent actions. Constant repetition of the same stimulus produces a katabolic condition of the receptors (fatigue) which tends to weaken or inhibit the response. This effect disappears after a period of rest.

(*b*) The *adaptation* effect acts in the opposite way. It is not an impairment of the response through weakening of the impulse, but a distinct improvement due to more perfect adjustment. In neural terms, it is not the effect of katabolism, but the formation of new nerve paths or increase in the efficiency of old paths. Adaptive modification of response is characteristic of intelligent behavior, and differentiates it from instinct.

Although the instinctive type of behavior predominates in subhuman species, a certain degree of adaptive modification through individual experience occurs in all animals except possibly those well down in the scale. Experiments with the maze [Fig. 27] demonstrate this. An animal is released at the entrance (A) of a maze, food having been placed at the

far end or center (B). The hunger stimulus, reinforced by the odor stimulus, arouses his locomotor activity. He starts off and after a certain number of hesitations, false moves, and retracings reaches the food and satisfies his hunger. The

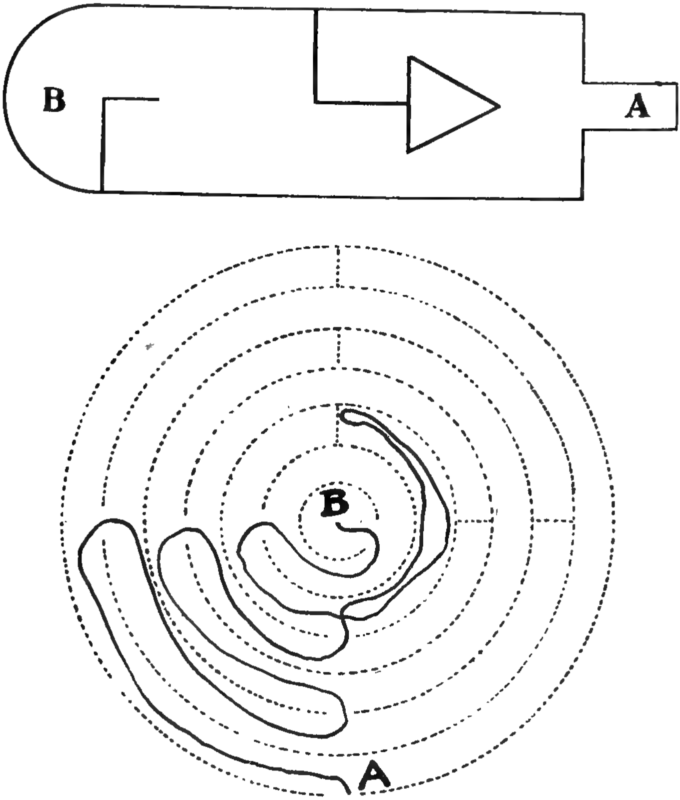


FIG. 27. — MAZES FOR INVESTIGATING HABIT FORMATION

Two mazes used in experiments on rate of learning path from A to B. Upper figure is a simple type used by Yerkes with frogs. One choice of paths at start, one choice near end. [From Harvard Psychol. Studies.]

Lower figure, maze used by Hubbert with rats. Heavy line shows actual path of one rat on 62d trial. See Table VI, p. 123, for results of this experiment. [From *J. of Animal Behavior*.]

same program is repeated on the same or successive days. It is found that after a number of trials the animal succeeds in reaching the food-box in a shorter time, and with fewer false moves as indicated by the total distance traversed. In an experiment with 27 white rats the average time was reduced from 467 seconds in the first trial to 40.3 in the eleventh, and the average distance from 4216.1 to 1029.8 cm.[1] Even in species as low as the crayfish and other crustacea there is a slight reduction in time and distance after many trials in a simple maze.

Adaptive modifications[2] of behavior are not limited to improving the *efficiency* of responses. The most important modifications are those which bring about *new modes* of response. Human behavior is far more subject to this kind of modification than the behavior of any subhuman species. In the human child we observe any number of instances in which new forms of response are developed through individual experience: talking, manipulating knife, fork, and spoon, buttoning the clothes, opening the door, climbing stairs, folding a napkin, writing, swimming,[3] riding a bicycle, etc. The three last are occasionally developed in later life. Generally adult acquisitions are concerned with more complex processes, such as steering a sail-boat or motor-car, typewriting, telegraphing, shooting, etc.

The growth of adaptive modification is illustrated in the behavior of the child at various ages when confronted by a closed door. A very young child will respond by weeping or calling out. As he grows older he may push upon the door or pound vigorously — two alternative modes of response which are both quite different from the earlier. Later the child may

[1] See Table VI, p. 123.

[2] It is usual to distinguish between *modifications*, or changes individually acquired, and *variations*, changes brought about in the germ cell and inherited in the individual.

[3] Learning to walk is due to the growth of inherited paths and belongs rather among the modified instincts (ch. vi).

shake the handle, and finally he may turn it and push or pull on the door. This last form of response persists and the others are suppressed.

Intelligence is the capacity to acquire and perfect new modes of response through individual experience. This capacity depends upon the presence of certain conditions in the neural constitution of the organism:

(1) The central system must contain alternative neural pathways. This condition is fulfilled if the central neurons are provided with a number of collaterals connecting with various higher and lower neurons.

(2) The connection with these collaterals must be plastic; that is, certain synaptic connections must not be so firmly established by inheritance that the impulse will always pass over one path to the exclusion of other alternatives.

(3) The resistance at alternative synapses must be capable of change independent of one another, so that a pathway which at one time is a line of greater resistance to the passage of the impulse may later on become the line of least resistance.

In man an intricate inherited system of multiple connections exists in the higher centers and particularly in the cortex of the cerebrum. This complex system includes a vast number of alternative paths which fulfil the above conditions. The complexity of the human cortex is an essential condition of man's superior intelligence as compared with other species.

Intelligence and Habit. — We have noticed the division of intelligent behavior into *habits*, *communication*, *rational actions*, and *conduct* (ch. ii). The three last are higher stages of development which may be left for discussion till later chapters. The fundamental type of intelligent activity is *habit.*

The term *habit,* like instinct, has been used in a variety of ways. In contemporary psychology it denotes a more or less fixed mode of response which has been acquired individually. The process of acquiring a habit is called *habit-formation* or *learning*.

Some writers draw a distinction between intelligence and habit, on the ground that intelligent behavior is subject to constant modification, while habits are fixed. In reality, the antithesis is only partial. Even where no firmly established habit exists, there are cases where the most ' intelligent ' or suitable response will be repeated time and time again; and on the other hand deeply fixed habits are usually essential factors in the most plastic, intelligent modes of behavior.

For instance, certain persons are ambidextral; but even with such individuals it is more suitable to use the right for hand-shaking, since the *other person* customarily extends his right hand, and the clasping of two right hands is easier than right with left. Hand-shaking behavior therefore tends to take a definite form even before it becomes fixed as a neural habit.

The organization of intelligent behavior is a continual process of habit-formation. Letter-writing is a typical intelligent activity; yet an essential factor in its successful accomplishment is a deeply fixed habit of manipulating the pen and of forming each letter or word in a definite manner. Every intelligent response consists in large part of habitual movements or well established motor attitudes.

The Learning Process. — The term *learning* is used to denote the process of forming new connections in the nervous arc and perfecting such connections through repetition. It includes both the process of motor habit-formation and the acquisition of ' central ' habits. When we memorize the multiplication table or learn to think logically, the acquisition is central rather than motor.[1]

Learning, or habit-formation, includes two opposite factors: (*a*) a tendency to *alter* the response (or the central process), and (*b*) a tendency to respond (or to think) repeatedly *in the same way*. The learning process which is typical of intelli-

[1] The central material of mental life will be examined in later chapters; since the learning process is the same for thoughts as for motor acts it is convenient to discuss both phases together.

gence may therefore be explained as the result of coöperation between two distinct and opposite processes, called *Acquisition* and *Fixation*.

a. Acquisition. — Acquisition is the process of establishing new paths of neural conduction in the central part of the nervous arc. *Instinctive* acquisition is a racial product and depends upon the structural evolution of the nervous system. *Intelligent* (or individual) acquisition is not due to the development of neural structure. It does not involve the formation of new neurons nor the projection of new collaterals. The neurons concerned are already in existence and all the branches which interconnect them have been formed in prenatal life. Neither does it involve extension of the dendrites, axons, or collaterals of existing neurons.[1] The interconnecting lines of conduction and synapses are usually present long before the actual physiological connections are made.

Intelligent acquisition depends rather upon changes of relative resistance at alternative synapses. There is either increased tension at certain synapses, so that the impulse is diverted from the path which was previously the line of least resistance; or else the tension at alternative synapses is decreased so that the nerve impulse passes across at these points more readily than heretofore. In either case the path of neural conduction is altered, provided the change of tension is so great that the relative resistance of the two lines is reversed.

Just what causes this altered resistance has not yet been fully determined.

(1) Change in relative resistance may be brought about by metabolic variations in the synapses themselves, due to different nutritive conditions at the several points. If the synapse between A and B1 [Fig. 28] undergoes katabolism while that between A and B2 undergoes anabolism, the path of the impulse may be shunted from A — B1 to A—B2.

(2) A condition of lessened tension in the neuron connect-

[1] See Fig. 4, p. 34.

ing at one of the alternative synapses may increase the permeability of that synapse. This may occur if an impulse from another path pass through this higher neuron simultaneously with the given impulse or just before it. If an impulse pass

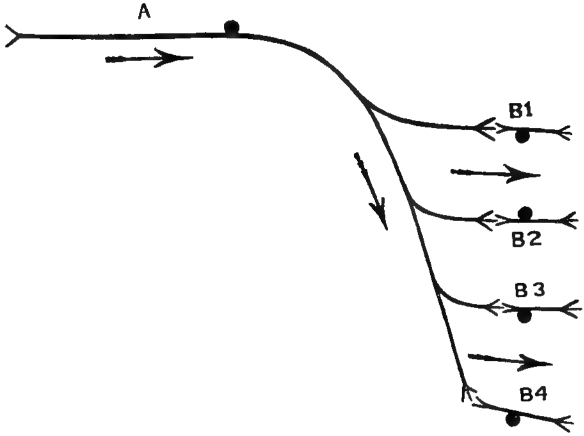


FIG. 28. — CHANGES OF PATH IN HABIT FORMATION

Diagram to illustrate the shunting of impulses from path A — B1 to path A — B2, etc. (See text.)

through the neuron B3 at the same time as the impulse in A, the tension between A and B3 may be so lessened that the impulse in A will take the path A—B3 instead of A—B1.

(3) A third cause of change may be the intensity of the present stimulus. The impulse may be so intense that it will not only pass over the usual synaptic path from A to B1, but will also drain out through other synapses into B2, B3, etc., at the same time; just as a heavy stream of water may fill the usual channel and find its way along other lines besides.

(4) Finally, the resistance of a synapse may depend upon the mode of the retention trace in the further neurons. If the mode of the nerve impulse has the significance which we have suggested (ch. iv), then the impulse will pass more readily into

a neuron which has formerly been *affected by the same kind of impulse* and which has retained a set corresponding to this mode. Thus if the present impulse in A be similar in mode to the trace in B4, it may take the path A — B4 instead of the path A — B1.

It seems probable that alterations in nerve paths are due to each of these factors: (1) varying metabolic condition of the synapses; (2) varying tension in the higher neurons; (3) intensity of present impulse; and (4) modal relation of present impulse to the retention trace in the higher neurons.

Of one thing we may be reasonably assured. The change in the neural connections is not due to a mysterious guiding agency outside of the nervous mechanism. There is no ground for assuming the existence of a sort of telephone operator within us, whose duty it is to plug in certain connections and remove others. The shunting process which leads to new acquisitions depends upon neural conditions, and upon the nature of the impulse itself.[1]

We may group the operations concerned in acquisition under three heads: (1) *Accommodation*, or formation of new paths. (2) *Inhibition*, the blocking of old pathways. (3) *Central reinforcement*, coöperation of simultaneous impulses in the higher centers. The laws of acquisition may be stated in terms of these three processes.

(1) LAW OF ACCOMMODATION: New pathways may be opened by the occurrence of anabolism at some synapse or in some connected higher neuron, or by the extreme intensity of the present impulse, or by modal similarity between the present impulse and the retention trace in some connected neuron. This brings about a new form of response.

(2) LAW OF INHIBITION: A pathway hitherto used may be blocked by katabolic conditions in some synapse or furtherlying neuron, or by modal dissimilarity between the present

[1] See Appendix, "Conscious Purpose," p. 427; "Personification of Natural Phenomena," p. 433.

impulse and the retention trace in some neuron in the circuit. This checks the customary form of response.

(3) LAW OF CENTRAL REINFORCEMENT: A central process which occurs simultaneously with a given impulse or immediately precedes it, may open a new path of discharge for the latter and thus produce a new response or a more complex mode of response.

The operation of these laws may be readily noted in many of our adaptations to new situations. In reading aloud, when we see a new word the nerve impulses are shunted into various neurons whose retention traces correspond in mode to the several letters or syllables in this word; the result is an accommodation of response. When we see a familiar figure approaching we prepare to greet the individual in one of the usual ways; if on closer inspection it prove to be a stranger, the mode of impulse becomes altered, and the bow or salutation is inhibited. When we are walking to the station and hear the whistle of our train the auditory impulse combines with the impulses concerned in the act of walking, and this central reinforcement brings about a new — in this case a livelier — motor response.

A case of inhibition combined with accommodation is observed when we start to wind a clock. If we find that the key does not readily turn in one direction we thereupon alter the course of the motor impulse, which results in our turning the key in the opposite direction.[1]

b. Fixation. — *Fixation* is the second general operation involved in habit-formation. It depends upon the repetition of impulses of the same sort. If the same mode of impulse recur over and over again, this repetition tends to improve the synaptic connections in the central neurons through which the impulse passes, and thereby increases the tendency to motor discharge along the same pathway. The result is

[1] Charles Lamb gives an amusing instance (not to be taken literally) of non-acquisition in his essay on Roast Pig.

brought about more quickly by very intense stimulation; that is, in case of powerful excitation the improvement advances more rapidly and fewer repetitions are needed. Since the condition of the synaptic connections is subject to alteration from time to time, fixation advances more rapidly also if similar impulses recur before too long an interval elapses.

Thus after a new path has been acquired, the new mode of response to which it leads tends to become fixed by (1) *repetition* of similar impulses, and the process is aided by (2) the *intensity* of the impulse, and by (3) the *recency* of the acquisition.[1]

The rate of progress in fixation is greater if no conflicting mode of response occurs meanwhile which would open up different paths of discharge. Fixation is impeded when after starting to learn on one typewriter we change to another machine with a different keyboard; here we are brought face to face with conflicting modes of response, which retard the fixation of definite paths.

The measurement of the progress of fixation in units of increased speed and decreased errors is an empirical problem which has been investigated for many common habits. Experiments on the rate of learning have been made in the case of typewriting and other definite habits, such as telegraphy, juggling balls, shorthand, mirror-writing,[2] etc.

An interesting practical problem in this connection is whether progress in fixation is more rapid where the repetitions are crowded into a short period of time, or where they are spread out over a longer period interspersed with intervals of rest. Contrary to the general impression, it has been found that progress in memorizing is faster in the long run with shorter practice periods interrupted by rather long rest

[1] See ch. xvi, "Laws of Ideational Suggestion," pp. 338–342.

[2] Mirror-writing by looking into a mirror and making letters which look correct in the mirror) involves the breaking up of deeply fixed habits. The experiment is easily arranged and gives interesting results.

intervals. But the progress in memorizing a set speech is faster if it be learned *as a whole* than if it is split up into parts and each part is learned separately.

Fixation is characterized by two distinct changes in the neural operations. (1) Increased ease of connection among the neurons, whereby the time of reaction is shortened. This effect is called *facilitation.* (2) Weakening of diffused impulses at the coördinating centers, so that certain accompanying movements which play no definite rôle in the act gradually drop out. This is called *elimination.* The laws of fixation may be stated as follows:

(1) Law of Facilitation: Repetition of the motor discharge along a newly acquired path improves the connections of the neurons through these synapses, and thereby renders the new mode of response *quicker* and easier.

(2) Law of Elimination: As the new connections improve, the motor discharge tends to pass over the given path with less diffusion over other paths; this results in cutting out useless movements and increases the *precision* of the response.

These laws may be verified by examining the fixation of some common habit, such as typewriting. After continued practice we find it easier to strike the right key, and the operation proceeds more quickly. At the same time useless movements are avoided; the finger descends directly on the proper key, instead of hovering over the keyboard. There are fewer eye movements of search. The subject no longer wrinkles his brow, puckers his lips, and breathes hard. One can readily note in himself any number of useless movements, due to diffuse discharge, when he undertakes the formation of a new habit.

The balancing movements of a child when he begins to walk furnish another illustration. The disappearance of these useless movements means that the entire nervous energy is directed along the appropriate path; in terms of response it means greater precision. An instance of complete fixation is

the case of learning to locate an electric-light switch quickly in the dark.

TABLE VI. — PROGRESS OF LEARNING

A. Habit Formation in the Rat:

Trial	*Av. Time (sec.)*	*Av. Dist. (cm.)*
1	467.0	4216.1
6	186.6	1719.2
11	40.3	1029.8
16	25.5	868.4
21	24.2	739.9
26	26.1	756.5
31	31.8	593.2

Average attainment of 27 white rats in maze experiment. Two trials each day; animal allowed to feed after second trial. (H. B. Hubbert, *J. of Animal Behavior*, 1914, 4, p. 63.)

B. Habit Formation in Man:

Day	*Av. Time (sec.)*	*Av. No. of Errors*
1	79	29
2	72	27
3	63	14
4	60	10
5	56	7
6	54	4
7	53	2.5
8	49	2
9	47	0.25

Average attainment of 4 human subjects learning to typewrite nonsense groupings of 7 different letters, arranged in a series of 55 letters. The series was performed 3 times daily. Table shows average time and average number of errors per series. (J. H. Bair, Psychol. Monograph, No. 19, p. 17.)

Table VI gives the results of two experiments on motor learning — one with white rats, the other with human adults. In each case the increase in facilitation is shown by the diminution of time (column 2); elimination of useless movements is indicated in the first case by decrease in distance traversed, in the second by decrease in the number of errors (column 3). Fig. 29 shows the progress of facilitation in learning to telegraph. The curve represents the number of words 'tapped off' in five minutes on successive days.

Adaptation to New Situations. — It is seldom that we find ourselves twice in exactly the same situation. While the general situation may resemble some past experience, there are

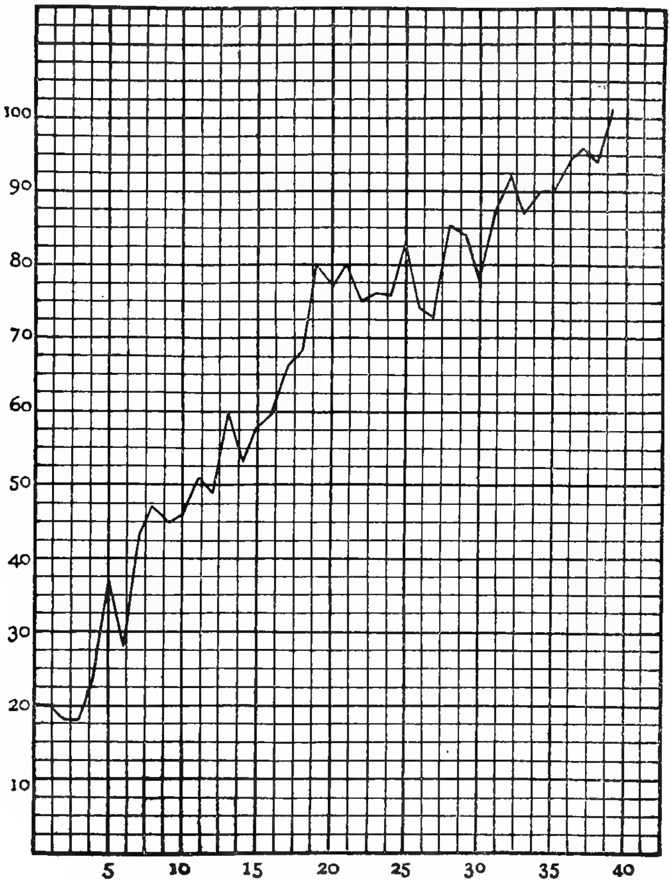


FIG. 29. — CURVE OF LEARNING

Vertical numbers denote number of words which observer was able to telegraph in 5 minutes after 30 minutes of practice. Horizontal numbers denote successive days of trials. Total unfamiliarity with habit at start. [From Swift, in Psychol. Bulletin.]

usually significant differences between our surroundings in the two cases. When we set about to dress, our clothes are not always in the same place. We have different errands to perform daily on our way to business. We study different subjects and write different lectures on successive days.

The fixation of certain modes of activity enables us to perform the stereotyped portions of our responses to the present situation. But how comes it that our responses to the *new* factors in the situation are usually fit or suitable? The modifications of response described under acquisition may or may not result in making the outcome more suitable. Yet in a majority of cases the modified response is fairly well adapted to the situation if the latter is not altogether novel. This adaptation requires explanation.

There are two ways in which adaptation is attained: (1) through *trial and error*, and (2) by *mnemonic combination.*

(1) Trial and Error adaptation depends upon inhibition and the persistence of the nerve impulse. If the response to a novel situation is not suitable, it frequently results in checking the motor impulse and starting a discharge along some other pathway. Inhibition may occur again if the second response is unfit, and so on till an adapted response is 'hit upon.' This type of adaptation occurs in solving a problem or puzzle, in inventing apparatus, in finding one's way, etc. It does not produce immediate success, and does not account for the high degree of adaptation exhibited in human behavior.

(2) Mnemonic Combination, or associative memory, depends upon the fact that in most situations, although the grouping of stimuli is novel, the elementary components are individually similar to previous stimuli. These elementary stimuli in the past have left retention traces in the central nervous system. When the same stimuli recur in a new grouping the pathways bearing these traces will (it is assumed) be brought into connection, and will be combined in new ways.

This will modify the form of response. Since the separate retention traces were due to conditions which resemble the present, the new response will tend to be adaptive. It is owing to such mnemonic combinations that our dressing proceeds smoothly even when our clothes are hung in a different closet or stowed away in another drawer, that we perform different errands on successive days, consult different text-books, and so on.

Behavior based upon mnemonic combinations is adaptive insofar as the elementary responses which it involves are adaptive. In adult life the simpler habits have already been formed. Hence our behavior in complex situations involving combinations of simple habits tends to be adaptive also. But it is not always so. We sometimes go to the desk or bureau to get something and stand helpless, having forgotten what we were after. Or we search everywhere for our pencil only to find it at last behind our ear. Occasionally in complex actions the mnemonic combinations are crossed. We light our cigar with a match, toss the cigar away, and start to put the match into our mouth. These failures in adaptation are rare, however, compared with the successes.[1]

Growth of Intelligence. — Intelligence, like instinct, is a phylogenetic growth. It evolves gradually from lower to higher species of animals as the nervous system increases in plasticity. The maze experiments described above furnish a measure of quantitative progress as we ascend the animal scale. The qualitative progress of intelligence is determined by testing the ability of various species to open gates or problem-boxes with complicated fastenings, and to solve other complex problems. The chief interest of such tests in relation to human psychology is the wide gap which they reveal between the highest subhuman modes of intelligent behavior and those exhibited by the human adult. The intermediate steps

[1] The central processes involved in adaptation will be discussed later. (See especially chs. xi, xiii, xix.)

are supplied by the successive stages of mental development in the human child.[1]

Biological or vital growth is characterized by changes and differentiations of structure. Mental growth is ' functional ' development; it is characterized by greater coördination of response or greater complexity of the central integrations. Moreover, it is determined by present capacity rather than by past accomplishments. The stage of intelligence which a given individual has reached is measured not by what he has actually accomplished but by what he is able to do. When we say that man ' can draw,' we do not mean that he has made every possible movement used in drawing, but that his movements are so coördinated that he is capable of combining drawing movements of various sorts with great precision. When we say that a man can speak English we do not mean that he has uttered every word in the dictionary, but that he is capable of uttering a large number upon their being suggested.

This applies to integration as well as to coördination. A man is said to know how to extract square roots even though he has never extracted every square root under a million. The measure of his stage of development is his ability to perform the process in any sample case. In other words, growth in behavior (and growth in organization of conscious experience as well) means a certain *capacity*, not necessarily an actual *attainment*. This distinction applies alike to reflexes, instincts, and intelligence.

In the human species intelligent behavior develops gradually and may continue to progress until far beyond middle life. Each intelligent act depends upon the perfection of certain component acts and when perfected may lead in turn to more complex developments.

The act of writing depends upon our ability to move the

[1] It is well worth while to observe closely the acquisition and fixation of relatively simple habits in the child at various ages.

fingers and wrist so as to trace each letter in the proper way. This in turn is dependent upon our ability to hold a pen or pencil properly. After we have learned to form the letters by means of certain wrist and finger movements we extend the act to other muscles, as when we write large upon the blackboard. Again, certain elements in the act of writing are utilized when we learn typewriting or typesetting, while other elements used in handwriting are lacking in both of these acts. Owing to the intricate interconnection of the various brain centers in man an almost infinite number of such new combinations are possible. These new manifestations are not due merely to differences in the stimuli, as in the case of instinct, but they constitute new centrally determined modes of behavior.

Significance of Intelligence. — When a motor habit is firmly established the act is often carried out with quite as much ease and precision as an instinctive act. On this account fixed habits are sometimes regarded as instances of 'lapsed' intelligence. According to this view the essential feature of intelligence is the acquisition of a new motor response, adapted to the situation.

There is another reason why fixed habits are sometimes regarded as lapsed intelligence. Intelligence is popularly supposed to depend on *consciousness* to guide and direct the responsive impulse into appropriate channels. But adaptive responses sometimes begin in a purely accidental way; in other cases an individual modification of behavior may be started by 'social imitation' of the actions of another being. Both of these types are intelligent acquisitions: yet they do not depend upon a "guiding activity of consciousness" operating apart from neural processes. Even in the higher types of intelligence, such as rational actions, it is held by many psychologists that the thought processes which precede the response are subjective manifestations of neural activity.[1]

[1] See Appendix, "Subjective and Objective Phenomena," p. 413.

We may accordingly reject the view that intelligence consists essentially in our *becoming aware* that one mode of behavior is suitable and another mode unsuitable. Fixed habits appear to be no less characteristic of intelligence than new acquisitions. Intelligence means the progressive adaptation of response to the conditions of the environment, by means of individual modifications. Fixation and acquisition are equally important factors in this process.

An illustration of the practical working of intelligence is found in the act of dressing oneself in the morning. There are certain garments to be put on; some of them require a fixed order (stockings before shoes, etc.), in other cases the order is indifferent (shoes and shirt). If we have learned a fixed order of dressing we complete the act more quickly and with fewer useless movements. Again, each particular act of dressing involves specific movements, some of which are quite intricate. Even the simple act of buttoning the coat involves a complicated adjustment of muscular movements.

The dressing process is not instinctive, but an individual adaptation. It is the result of a long and intricate learning process involving both acquisition and fixation. Without the high degree of fixation which we have gained through frequent repetition the very first item in our day's program would become an Herculean task. The fixation of movements, instead of indicating a *lapse* of intelligence, is really essential to the highest degree of intelligence and adaptive behavior.

There is a wide-spread popular notion that habits are bad things and should be avoided. We are continually warned not to get into a rut. Like most popular generalizations, this is partly true, partly false. Habits are useful and indispensable insofar as they fit us for coping with the conditions of life and in that they form the basis of more complex acquisitions. They are detrimental and undesirable when they become so firmly fixed as to prevent us from adapting our behavior to new conditions.

If we are so wedded to smoking that we waste valuable time at important junctures, or if we are so fond of telling anecdotes that we cannot readily adopt the rôle of listener, we are likely at times to lose certain business or social advantages. Almost everyone develops certain mannerisms and actions which in a minor way waste time and energy, or which are disturbing to others. Nervous movements, drumming with the fingers or tapping with the foot, hemming, coughing, and giggling are useless habits; a shrill tone of voice, uncouth table manners, whistling in public, and the like are socially annoying. All these may be classed as 'bad habits.' Still worse from a biological and psychological standpoint are such habits as intoxication or the use of drugs, which impair the vital processes and weaken the mental life.

While a distinction may be drawn between useful and detrimental habits, it seems impracticable to classify intelligent behavior under a number of general heads such as were found in the case of reflexes and instincts. An intelligent act, unless it be of a simple type, involves many neural paths and a variety of terminal organs; it usually serves to promote the *general mental life* of the individual and is not readily identified with any one specific vital function. Even the distinction between *social* acts, acts directed toward *individual welfare*, and acts concerned with the *general physical environment* is unsatisfactory; for in most human activities more than one of these factors is involved.

The difficulty of classification serves to emphasize the fact that intelligent behavior represents a response to the entire situation which confronts a creature, rather than a reaction to specific stimuli. Intelligence in its higher manifestations tends to express the *organism as a whole,* not merely some specific phase of organization.

In the complex types of intelligent behavior the all-important factor is *central adjustment.* The operation of adjustment is open to a new method of investigation. The method

of self-observation enables us to examine the central processes as 'mental states.' This study furnishes a far more characteristic view of intelligence than the behavior method. Beginning with the next chapter we shall examine the *central phenomena* of intelligent mental life as observed in our own individual experience.

Summary of Chapters V to VII. — Psychology deals with the interrelations between the organism and its environment which are brought about by the passage of impulses through arcs of the neuro-terminal system. The activity occurs in three successive stages, called *stimulation*, *adjustment*, and *response;* each of these depends upon the operation of one of the three segments of the arc (ch. v).

The operation of the entire neuro-terminal arc constitutes *behavior*. There are three distinct types of behavior: *reflex*, *instinctive*, and *intelligent*.

Reflex behavior is due to the formation of certain fixed and definite pathways in the neurons which constitute lines of least resistance to the passage of impulses. These pathways are determined by inherited configurations of nerve structure. In reflex action the stimulus excites a sensory impulse which leads directly through a center or series of centers to a motor path and thence to a muscle or gland, resulting in some definite response.

Instinctive behavior consists in a complication of reflexes which results in a complex response; it usually involves a series or chain of responses. The formation of pathways for the impulses concerned in instinctive behavior depends upon inherited nerve structure. Human behavior is rarely of the purely instinctive type, but it includes many *modified instincts* and *instinctive tendencies* (ch. vi).

Intelligent behavior, like instinct, is a complex response or a series of responses resulting from the cöoperation of several reflexes; but in intelligence the lines of connection are not due to inherited structure; they are built up by individual experi-

ence and perfected through repetition. The development of intelligent types of response is called *learning* or habit-formation; it involves the two factors of *acquisition* and *fixation.*

Behavior in general is *adapted* — that is, the response tends to meet the conditions of the environmental situation which stimulates the creature. This fitness of response is apparently due to natural selection, which operates either in race history (instinct), or in individual experience (intelligence). (Ch. vii.)

The central factors in intelligent mental life are open to investigation by the method of self-observation, and will be examined from this standpoint in the remainder of the book.

Collateral Reading:

Thorndike, E. L., Educational Psychology (briefer course), Part II.
Parmelee, M., Science of Human Behavior, ch. 14.
Judd, C. H., Psychology, General Introduction (2d ed.), ch. 9.
Woodworth, R. S., Dynamic Psychology, chs. 4–6.
Watson, J. B., Behavior, chs. 6–8.
Meyer, M., Fundamentals of Human Behavior, chs. 7–10.
Mellone, H. S., Elements of Psychology, ch. 7.
Swift, E. J., Mind in the Making, ch. 6.
Colvin, S. S., The Learning Process, chs. 1–4.
Rowe, S. H., Habit Formation and the Science of Teaching, chs. 3–5.
Ebbinghaus, H., Memory (trans.).

Practical Exercises:

Test the formation of some new habit. [This should be assigned two weeks ahead.]

Make a list of 'useless' and 'annoying' habits observed in those around you, including some of your own.

Practice mirror-writing, looking in the mirror attentively and with your hand concealed. Report any notable feature of the experience.

CHAPTER VIII

CONSCIOUS EXPERIENCE

The Method of Self-Observation and its Data. — So far we have considered mental life in terms of stimulation and response. These form the beginning and end of neural activity. Stimulation produces activity in the receptors and in the sensory segment of the nervous arc; response is the activity of the effectors determined by impulses in the motor nerves. The operation of stimulation and the operation of response are both open to scientific investigation by various 'objective methods.' The investigator can observe their phenomena readily in animals and human beings.

At the present time we have no objective means of observing the workings of the central neurons while integration and coördination are taking place. Physiology gives us little information about these central operations, and behavior study is concerned with them only indirectly.

Our objective knowledge of the activity of the central part of the arc is derived from a study of brain structure (especially the topography of various centers, areas, regions, and the way the centers are connected together by association fibers), and from a study of the general properties of neural activity. We do not know the precise manner in which this activity operates, nor the means by which the passage of a current through a given synapse is facilitated at one time and inhibited at another. These questions are not so important in the study of reflexes and instincts, where the action is fairly uniform; but our lack of knowledge of the central processes seriously hampers the study of intelligent behavior.

The deficiency in the objective data is largely compensated for by our ability to examine the central processes as they

occur in our own mental life. When certain nerve processes are going on in your own brain you are at the same time undergoing certain definite experiences; you see, you hear, you think, you are pained, you desire, you decide, etc. In other words, each one of us has what is sometimes called an *inside view* of the workings of his own neural processes. Since the terms ' inner ' and ' outer ' are likely to suggest the distinction between things inside and outside the body, it will be clearer to call an individual's self-observation of his mental life the *subjective* aspect of the central occurrences, and the observation of these same occurrences by another individual their *objective* aspect. Or we may call the data subjective and objective phenomena respectively.[1]

Subjective phenomena differ radically in appearance from objective. Our perceptions, memories, etc., are quite different from nerve currents, light vibrations, muscle contractions, etc., which we investigate with physiological and physical instruments. The differential feature of subjective phenomena is denoted by the term *consciousness.* In other words, consciousness is defined as the distinctive characteristic of subjective mental life. Subjective phenomena are termed *conscious experiences.*

The study of conscious experience forms a distinct branch of psychological investigation. It adds much to our information regarding mental life obtained by the behavior method, since it deals with a class of phenomena which objective methods at present can not reach. In human psychology the study of subjective phenomena by self-observation forms the larger part of the science; until quite recently it was supposed to embrace the entire field of psychology.

Casual and Scientific Self-Observation. — Every normal human adult can observe and does observe his own conscious experiences. This fact often leads to the notion that one can readily become a psychologist without studying or training.

[1] See Appendix, "Subjective and Objective Phenomena," p. 413.

The teacher of psychology constantly meets with this conviction among his students — especially when he reads the results of written examinations.

The fallacy here lies in the confusion of untrained observation with scientific observation. The same confusion appears in other fields of science. One can observe physical and chemical phenomena as readily as he can observe his own mental phenomena. In either case an untrained observer is likely to misread or misjudge the facts.

For ages it was assumed that a heavy body falls faster than a light body. Everyone observes objects fall to earth; the ancients (like the average man of to-day) took no trouble to observe the phenomenon accurately, and so the law of falling bodies was misstated until Galileo performed his crucial demonstration. In the same way the ancients, observing the gross form of material things, concluded that there are four elements in nature: earth, air, fire, and water. This traditional view persisted till Cavendish, Priestley, Scheele, Lavoisier, and other trained chemists separated hydrogen, oxygen, and other elements from their compounds by means of crucial experiments and determined their relations.

In psychology casual observation has given rise to a host of popular misinterpretations, some of which persist to-day. Almost everyone who has not studied mental life scientifically will assert that man has but five senses, with possibly a "mysterious sixth." The ancients regarded the heart as the seat of affection and the viscera as the seat of the powerful emotions. The average person is likely to think of his 'will' or 'volition' as a very simple phenomenon.

All the popular notions just mentioned are erroneous. Man possesses at least ten or eleven distinct senses; the emotions and affections, like other mental phenomena, are centered in the brain; volition is a very complex process, involving high development of the brain centers. In order to obtain a true knowledge of psychological principles it is necessary at the

outset for the student to rid himself of the conviction that his untrained observation of his own mental states is scientific psychology.

Scientific psychology began in an attempt to reduce the results of uncritical self-observation to a system. Some slight progress in this direction was made by Aristotle, who classified the senses, noticed the illusion of the crossed fingers, examined memory and association, and collected a quantity of general data. The reduction of this material to a system dates from the investigations of Descartes, Hobbes, and their successors in the seventeenth and eighteenth centuries. In its earlier stages the scientific work in psychology was based almost entirely upon self-observation, or *introspection*, as it was called. This purely subjective line of research culminated with Thomas Brown's *Philosophy of Human Mind* in 1822. Brown consistently rejects every attempt to correlate conscious experience with nerve activity.

Even before this time, however, it had become more and more evident that the states and processes of conscious experience are closely bound up with the activities of the nervous system, and during the past hundred years psychologists have come to recognize more and more the importance of studying the structure and functions of the brain. This led at first to the crude 'materialistic psychology' of Priestley and to the phrenology of Gall and Spurzheim. The phrenologists assumed that certain mental functions, such as combativeness, amativeness, etc., are centered in various parts of the brain, and that their degree of development in any individual may be determined by measuring the protuberances in the skull overlying the several regions.

The method of phrenology involves two errors: (1) The growth of the skull with its 'bumps' and depressions does not correspond by any means to the development of the brain beneath. (2) The mental faculties assumed by the phrenologists to be fundamental are now known to be highly complex

processes; the elementary forms and characters of conscious experience are quite different from these.

The development of scientific psychology based upon self-observation and neurology dates from David Hartley and James Mill; but the use of quantitative and experimental methods of research was not attempted on any large scale till later. Weber, Fechner, and Wundt are responsible for introducing these methods, which have made modern psychology a really quantitative science.

Characters of Experience: Quality and Intensity. — The experiences of our daily life are very complex phenomena. The acts of thinking and willing are made up of simpler processes. Even relatively simple states, such as feeling, seeing, remembering, are the results of combining certain elementary data which never occur separately in adult human experience, though they may be isolated in the child and in lower animals. Before examining the different kinds of conscious experiences, then, we must study the elementary factors and states which enter into their composition.

The factors which determine the nature of specific experiences are of two sorts:

(1) Conscious experience is determined by the nature of the *stimuli* which generate the nerve impulses. Variations in stimulation produce variations in consciousness. The independent kinds of variation brought about in this way may be called *characters* or attributes of experience.

(2) Conscious experience is also determined by the nature of the *neural processes*. The fundamental operations of nerve (ch. iv) produce variations in consciousness, and corresponding to each of these neural properties is an *operation* or property [1] of conscious experience.

The two statements may be combined in the following general law: *The form of central activity and conscious experience*

[1] *Operation* refers to the process, *property* is the capacity for change, or the type of effect resulting from the operation.

depends both upon the action of the environment and upon the specific operations of nerve.

The fundamental characters of conscious experience are *quality* and *intensity*. Quality corresponds to the *mode* of the impulse, intensity to the *intensity* of the impulse. These neural phenomena were discussed in chapter iv; the corresponding subjective phenomena will be examined later.[1]

Fundamental Operations of Experience. — Apart from the variety introduced into conscious experience by differences of stimulation, our mental states are altered by conditions within the nervous system. Each of the properties of nerve noticed in chapter iv is also a property of conscious experience. We may examine them again from this subjective standpoint.

1. **Impression.** — Impression is the mental operation or property of conscious experience which corresponds to *excitation* of the neurons. When an impulse reaches the higher centers, the human being whose brain is concerned *experiences* something. He sees, hears, remembers, etc. The capacity to receive these conscious experiences is called *impressibility;* the process is *impression*. Since all our observed experiences are due to activity in the cerebral cortex, impression can only be definitely assumed in connection with cortical activity. It is quite possible, however, that impressions occur also in the basal masses, cord, and sensory neurons.

2. **Suggestion (Successive Association).** — Suggestion or successive association is the property of conscious experience which corresponds to *conduction* of the nerve impulse. As the impulse passes from one central neuron to another it frequently changes in mode owing to the retention set of each neuron through which it passes and to other impulses which reach the brain at approximately the same time. In terms of self-observation, one conscious experience gives place to another, through the revival of former impressions or the occur-

[1] See especially chs. ix–xii.

rence of new sensations. This succession of experiences is often called *successive association* or association of ideas.[1]

The process of suggestion depends upon the progress of the nerve impulse in the central neurons. There are three possibilities: Either (1) the impulse may pass out into some motor channel; or (2) it may pass into some central neuron which is simultaneously affected by another impulse; or (3) it may pass into some neuron which has retained a set from previous impressions.

In the first case the result is expression; the nerve impulse in question has no further direct effect on conscious experience. It may lead indirectly to another experience. The sight of a friend may start in us a motor impulse to wave our hand; this movement in turn causes a kinesthetic stimulus which leads to renewed central activity and consciousness.

In the second case, where the impulse passes into a neuron affected by other impulses, the result is either a partial change in the form of experience or a complete change from one experience to another. This is one type of suggestion. Our visual experiences when we look at a book are combined with our kinesthetic experiences when we lift it; or they pass over into something quite different when we look away from the book to the window.

The third case, where the impulse passes into another neuron and is there transformed by the retention effect, is the typical form of suggestion found in human experience. In civilized man these suggestions constitute an important part of daily experience. A sensation or perception leads to a memory or a thought; this leads to another ideational process, and so on through a long chain of experiences. For example,

[1] These terms are open to misinterpretation. (1) In ordinary language 'association' includes *simultaneous* combinations as well as successions, but the process we are considering is always succession. (2) The flow of experiences or stream of consciousness includes successive *sensations* as well as successive *ideas*. The term *suggestion* meets both these difficulties.

I see the name of my former professor of history; this suggests the image of the man himself, his particular tone of voice, a phrase of his about Napoleon, the image of Napoleon, the French Revolution, the Russian Revolution, Tolstoi, etc. Unless the train of thought is interrupted by some new and potent stimulus it may proceed through one step after another for many minutes. The process of suggestion gives rise to the flow of thought, or in more general terms to the stream of consciousness (ch. xvi).

3. **Revival (Memory).** — Revival is the property of conscious experience which corresponds to the *retention effect* in the neurons. This operation is commonly called *memory*. The two terms may be used interchangeably provided we distinguish between the simple memory experience and definite memory images. Revival or simple memory may occur without a definite memory image. It includes the bare 'feeling of familiarity'; it covers also experiences which have not even this tinge, but are unrecognized reproductions of earlier experiences. An example of revival in a highly developed form is my experience when I recall with vividness and precision the scene and incidents at my brother's wedding many years ago. A less vivid revival is the feeling of familiarity when I see an old friend or hear a well-known piece of music. Revival occurs in the lower species as well as man, but there is no evidence in the lower species of long trains of ideas, or even of vivid memory images such as we observe in ourselves.

4. **Vividness (Attention, Focalization).** — Vividness is the property of conscious experience which corresponds to *variations in the metabolic condition* of the synapses. Such variations serve to facilitate or inhibit the discharge of the nerve impulse into the central neurons. When a synapse is fatigued, but is not wholly impermeable, the impulse which passes through it is damped or lessened in volume. As a result, the experience itself becomes less effective; it decreases in vividness. If a synapse is in prime condition, the impulse

passing across it retains its full vigor, with the result that the experience is unusually effective or vivid.

This character is commonly called *attention*. The term attention, however, has several other meanings: it is used to denote the motor accompaniments of vivid experiences, as well as the degree of intellectual interest which accompanies vividness. To avoid this ambiguity it is preferable to use the term *vividness* to denote the subjective accompaniment of metabolic variations. It may also be called *focalization*, since it renders certain portions of the total experience especially clear and prominent.

We should distinguish between vividness variations and the variations in intensity of experiences which are due to the nature of the stimulus. Notice, for example, the effect of three noises, one very loud, one of moderate intensity, and one so soft as to be scarcely heard. If these are repeated under varying conditions of 'focalized attention,' we observe that the very faint sound is at times more vivid than the very loud.

With stimuli of medium intensity all degrees of vividness may occur. When we listen to a lecture delivered in an ordinary tone of voice, certain phrases or sentences may be vividly impressed upon us, others may barely pass muster, while at times a train of thought may crowd the spoken words entirely "out of consciousness."

With unusually powerful stimuli the very strength of the stimulus itself is apt to give great vividness to the experience. With very faint stimuli other processes are likely to preponderate, so that the experience in question is likely to have a low degree of vividness. But even where a very intense and a very faint stimulus occur together the experience of the latter may be more vivid. It is said that the inhabitants of Niagara village scarcely hear the roar of the falls. Members of the New York Stock Exchange acquire great proficiency in picking out certain significant words from the babel of voices on the floor.

5. **Combination (Simultaneous Association).** — Combination is the property which corresponds to the *summation* of nerve impulses. It usually happens that several stimuli act upon different receptors at the same time and the impulses which they excite reach the brain together. These separate impulses may be collected into one neuron. The result is a single complex impulse in the brain, and a complex impression in conscious experience.

There are two different sorts of combination:

(*a*) FUSION, in which the elementary data are so merged that it is difficult to distinguish them. In fusion we experience a total effect, which is different from its separate parts. This is observed in the perception of a musical chord; the effect is apparently simple — we do not ordinarily pick out the constituent notes, although the practiced musician may do so.

(*b*) COLLIGATION, in which the elements remain distinct, although they are gathered together in a single experience.[1] Colligation occurs in our perception of colored surfaces, of the letters which make up a printed word, of the human face with its several features, etc.

In general, simultaneous impressions in the sense of hearing tend to group themselves by fusion, while impressions in the sense of sight are grouped by colligation.

Combination is sometimes called *simultaneous association.* The operation is quite different from successive association. In successive association certain elements of earlier experiences do hold over and combine with new elements in later experiences. This happens when we think of a door-knob and then of the door — the knob being an element in the latter thought. But the combining process takes place *after* the transition and is a distinct property of conscious experience. Combination is the 'synthetizing factor' of consciousness. It is an important factor in building up complex experiences, such as perceptions, general ideas, etc.

[1] The terms *integration* and *complication* are also used for this process.

6. Discrimination. — Discrimination is the property which corresponds to *distribution* of the nerve impulse. An impulse may pass partly through one synapse, partly through another, giving rise simultaneously to different impulses in two or more neurons further on in the arc. This is apparently the basis of our conscious discrimination between parts of the same total experience. For example, though we ordinarily perceive the human face as a whole, we are able to pick out any single feature from the mass and focus it. The vividness of the discriminated feature depends upon metabolic conditions at the various distributing synapses; but the discrimination itself is due to the shunting of a certain part of the impulse into a separate pathway. Discrimination is the 'analyzing factor' of consciousness.

7. Transformation ('Mental Chemistry'). — Transformation is the property of experience which corresponds to the *modification* of the nerve impulse. It occurs in connection with revival and also in fusion and colligation. When we recall an event our recollection is usually tinged more or less with some present sensory experience; the quality of the impression is transformed accordingly. In cases of fusion some elements in the experience may neutralize others wholly or to a certain extent, so that the total resulting experience is not precisely the sum of the constituent parts. The effect may be observed even in colligation. To the college student in his third year the campus and buildings 'look different' from their impression when he first arrived in town as a freshman. Or if we observe the word *cab*, the impression we get from this combination of stimuli is something very different from the impression aroused by the separate letters, *c*, *a*, and *b*. In all such cases the combination is attended by a qualitative change or *transformation* [1] of the experience.

Transformation is an important factor in mental life. It

[1] The terms *mental synthesis* and *mental chemistry* have been applied to this operation.

may occur even in the simplest combinations of sensations. When we perceive an orange the sensory data of sight, touch, heft, and smell are modified by the memory of taste, and the quality of the whole experience is transformed to a certain extent. When the present stimulus is weak and the retention effect is very strong the sensory experience is transformed into a memory image or an imagination. In complex experiences, such as a general idea or a thought, the original elements are still further transformed and it is difficult at times to determine whether the thought has any basis whatever in sensation.

Table VII gives a list of the fundamental operations of conscious experience. The corresponding neural operations are shown in the second column. The two sets may be regarded as different ways of observing the same occurrences. These properties are not isolated or separate phenomena.

TABLE VII. — FUNDAMENTAL OPERATIONS OF CONSCIOUS EXPERIENCE

Conscious Operation	*Neural Basis*
Impression	Excitation
Suggestion	Conduction
Revival	Retention
Vividness	Metabolic Variation
Combination	Summation
Discrimination	Distribution
Transformation	Modification

They denote merely the different ways in which the material derived from stimulation may be varied. Each operation is an independent variable.[1] In any given experience the effect of all or most of them may be traced.

Subconscious Experience. — It often happens that a stimulus produces no observed conscious effect at the time, yet later its effect is experienced as a revival; or it may not be discriminated and yet it may alter the quality of conscious experience. For example, we may not be aware of a clock striking the hour, but later we may recollect that it did strike and

[1] Except perhaps transformation.

often we can recall the exact number of strokes. Or, we may not be able to distinguish the length of two lines that are nearly equal, and yet we may 'guess' the longer correctly 60 times out of 100. This "consciousness which is not conscious" is called *subconsciousness.*

There are two distinct sorts of subconscious phenomena: (1) A central impulse, whether weak or strong, which is not connected up with the chain of central neurons whose activity constitutes our present personal experience. (2) An impulse whose degree of vividness is so slight that it falls "below the threshold" of sensation. We may call the former *subordinate consciousness,* and the latter *subliminal consciousness.*

The older psychology was inclined to doubt the existence of *subordinate consciousness* or rather to deny that phenomena which are not subjectively observed may properly be treated by the 'introspective' method. This objection was met by the discovery of cases in which the subordinate material is highly organized and yields a co-conscious personality. Certain hysterical patients have been found with two or more distinct, organized personalities. In one state, A, they apparently lose all connection with the experiences belonging to the other state, B. When personality B reappears the memories, feelings, and attitudes which characterized this state on former occasions return and constitute the background of the individual's mental life (ch. xviii). Each state is evidently an organization of conscious experiences; yet each may be wholly cut off from the organization of the other.

It seems equally probable that the lower centers are capable of experiencing organized impressions. It may be assumed that the striking clock is actually heard, though not in relation to our dominant conscious life, and that the nerve impulses concerned in our fixed habits constitute 'conscious experiences' of subordinate centers, even though they fail to connect with our higher mental organization.

A recent development of psychology started by Sigmund

Freud goes to the other extreme, maintaining that *all* our conscious experiences are controlled by our subconscious life. The mistake of this theory lies in assuming that our subordinate conscious experiences constitute a single, highly organized personality. The subordinate mental life of most individuals consists probably of a number of separate, partly organized experiences, which are utilized as material by the fully organized mental life ('personality') of the higher central areas.

The notion of *subliminal consciousness*, which is supported by such facts as the judgment of nearly equal lines, has given rise to another extreme view. Clairvoyants maintain that their subliminal impressions are capable of such intensification that they become vastly more vivid than experiences of superliminal intensity. It is probable that in the hypnotic state impressions of subliminal intensity may be magnified at times in this way. The texture of blank sheets of paper may be discriminated by a hypnotized person so that he identifies one sheet as a photograph of A, another as a photograph of B. The general character of these phenomena, however, is open to serious question.

Marginal Consciousness. — In any complex experience the component parts tend to assume different degrees of vividness. Usually a certain group of data are focalized, the remainder taper off into obscurity. Visual experiences afford a ready illustration of this. Objects at the center of vision are focused; those at the periphery may be scarcely noticed. The same is true of every complex experience, even where various senses are combined. The obscure elements which enter into the experience are called the *margin*, *fringe*, or *penumbra* of consciousness; they form at times a background to the vivid, focalized consciousness, or give a distinctive *timbre* to the total experience.

These terms are used somewhat figuratively; the marginal elements are not always situated side by side with the focal elements. The heaviness we observe in looking at an iron

crowbar is marginal, though we localize it *in* the visual object.

The marginal components often play as important a rôle in the experience as the vivid focus. We shall notice this particularly in examining the attitudes which form the background of mental life (ch. xvii).

Hyperesthesia and Anesthesia. — In comparing the same individual's experiences at different times it is found that with the same intensity of stimulation the degree of *total* consciousness may vary considerably. At times every stimulus, even one below the usual threshold, yields a vivid experience. This is called a condition of *hyperesthesia.* At other times the threshold is raised far above the usual level, so that a stimulus of medium intensity yields no conscious experience whatever. This condition is called *hypesthesia.* The limiting case, where even the most intense stimulation of a given receptor yields no experience, is called *anesthesia.*

These special conditions are brought about by physiological agents working upon the receptors or nerves. The application of certain drugs to the receptors produces local anesthesia. Narcotics introduced into the system produce general hypesthesia or anesthesia. Stimulants similarly applied produce local and general hyperesthesia respectively.

All such special conditions are the result of metabolic variations in the neurons or receptors, brought about by unusual metabolic activities in the organism. These general physiological changes affect either the central neurons, or the sensory neurons, or the receptors.

The peculiar phases of conscious experience which occur in *sleep* and *hypnosis* will be discussed later (ch. xvi).

Fundamental Types of Experience: Sensation and Ideation. — In the preceding sections we have examined the elementary factors which affect conscious experience. These external forces and neural operations, working together in various ways, bring about various kinds of experiences. Cer-

tain of these types have been referred to from time to time in our illustrations. We have spoken of sensation, perception, emotion, memory, and volition. These and other types will be examined presently. We shall find that they exhibit different degrees of complexity. Some types are more fundamental than others.

The most fundamental division of conscious experience is into two distinct types, one of which is determined chiefly by forces *outside* the nervous system, the other by certain conditions *within*. The mode of the central impulse is determined (1) by the mode of the stimulus, (2) by the retention effect and other neural properties. There are two corresponding types of conscious experience, according as one or the other of these classes of factors predominates. They are termed *sensation* and *ideation* respectively. If the quality of the experience be determined wholly by the stimulus, the experience is 'pure sensation'; if the quality be determined wholly by the retention effect, regardless of present stimulation, the experience is 'pure ideation.'

As a matter of fact no adult human experience is either purely sensational or ideational. When we are impressed by a stretch of white wall, a pervasive odor, a thundering noise, each of these experiences is almost entirely a sensation; yet each suggests to us some previous experience or is at least 'colored' by the general effect of our past life. On the other hand, a train of memories and ideas is almost wholly ideational; but it is always tinged by the organic sensations and feelings present at the time, if not by stimuli from outside our body. This is shown, for example, by the radical difference in the flow of thought according as we are depressed or elated.

The distinction between sensation and ideation is highly significant in the study of mental life. Since psychology is concerned with the interrelations between the individual and his environment, it is of prime importance to distinguish

between impressions which originate outside of the neurons and impressions due to the condition of the central neurons themselves. An idea — that is, an impression whose mode is determined by the retention effect in the neurons — is related only indirectly to the present environmental or bodily conditions.

The retention effect is always due to previous nerve impulses, and these are originally determined by the mode of stimulation. Hence every idea is based upon sensory experiences which have occurred in the past. It follows that sensation is the *original* and ideation the *derivative* type of experience.

The entire group of sensations furnished by each sort of receptor is called a *sense.* Thus the sensations resulting from stimulation of the eyes are grouped together and called the *sense of sight* or vision; the sensations mediated by a certain kind of corpuscle in the skin constitute the *sense of touch;* and so on.

In the next two chapters we shall examine each of the senses separately, beginning with the sense of sight, which is the most highly developed sense in man and plays the most important rôle in his mental life.

Summary of Conscious Experience. — *Conscious experience* is the name given to phenomena of central nerve activity when observed directly by the being in whom this activity is operating.[1] The two *characters* of experience, *quality* and *intensity,* are determined primarily by the mode and intensity of the stimulus. The seven fundamental *operations* or properties of conscious experience correspond to the properties of nerve

[1] There are several other definitions of *conscious experience,* and other ways of interpreting the relation between conscious experiences and 'brain states' besides the double-aspect view. For sake of simplicity the subject has been treated from this standpoint, with no reference to the 'philosophic objections' which have been urged against the interpretation. The reader should remember that the relation between 'subjective' and 'objective' phenomena is still a matter of hypothesis. (See Appendix, p. 413.)

substance (Table VII). The fundamental *types* of experience are *sensation* and *ideation*, which depend respectively upon stimulation and central retention effect. Sensation is the *original* and ideation the *derivative* type of experience.

Collateral Reading:

Angell, J. R., Psychology, ch. 4.
James, W., Psychology, chs. 11, 13, 15, 16.
Titchener, E. B., Text-Book of Psychology, secs. 1–5.
Wundt, W., Introduction to Psychology (trans.), chs. 1, 2.
Breese, B. B., Psychology, chs. 12, 18.
Judd, C. H., Psychology, General Introduction (2d ed.), ch. 6.
Holt, E. B., Concept of Consciousness.
Marshall, H. R., Consciousness.
Spencer, H., Principles of Psychology, Part I, ch. 7; and Vol. II, pp. 505 c-d.
Freud, S., Psychopathology of Everyday Life (trans.).

Practical Exercises:

Analyze your 'total experience' at some moment, e.g., three minutes ago, noting especially (*a*) its variety, (*b*) grouping into objects, thoughts, acts, etc., (*c*) attention and inattention to various parts.

Describe any experiences of anesthesia or hyperesthesia in your own recent life.

Examine how finely you can distinguish between colors seen in different rooms at very different times; compare with discrimination of colors side by side (with black or white border between).

CHAPTER IX

THE SENSES

In studying each sense the following phenomena will be examined: (1) Structure of the receptor, (2) Physiology of the receptor, (3) Nature of the stimuli, (4) Qualities of sensation, with other special phenomena of the sensory experience.

1. Sight (Vision)

Structure of the Eye. — The specific receptors for visual stimuli are the rods and cones in the retina of the eye. These are affected by light waves, and they are affected in different ways according to the intensity and mode of the stimulus. But broadly speaking the receptor organ for sight is the *whole eyeball*, together with the muscles which produce and regulate its movements.[1] [Fig. 30.]

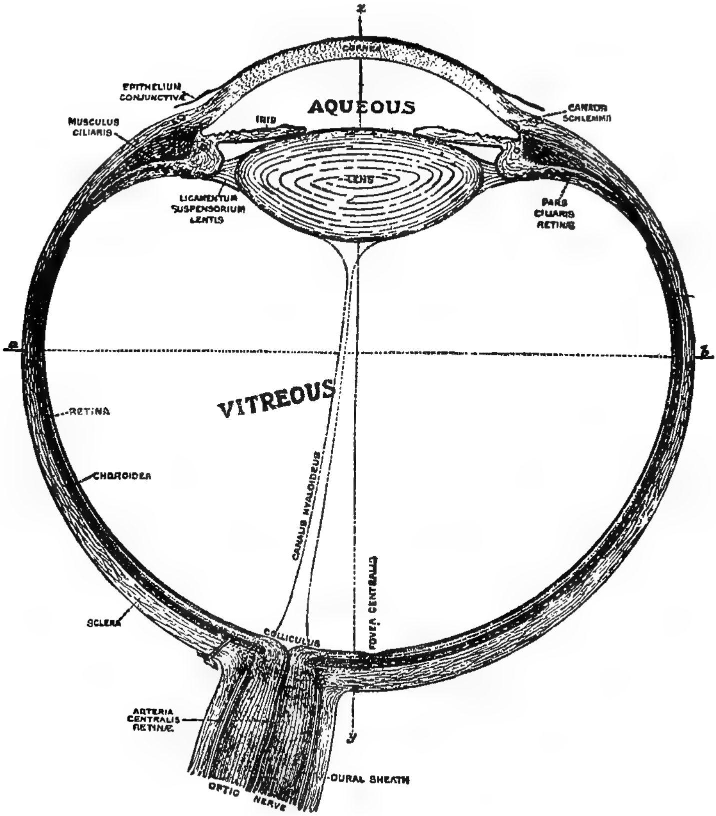
The eye consists of a nearly spherical body. Its outer coating is a tough white substance called the sclerotic, which covers the entire eyeball excepting the extreme front surface. The front surface of the eyeball consists of a transparent coat called the *cornea*.

Inside the eyeball, slightly behind the cornea, is the *lens*, a transparent disk which is convex on both its front and back surfaces. The lens is held in place by a circular muscle, which also, in connection with an accessory muscle, serves to regulate its shape. When the accommodation or *ciliary muscles*[2] contract, the lens bulges out; as these muscles relax the lens flattens. The interior of the eye behind the lens is filled with a tough, transparent, jelly-like substance called the *vitreous* body. The vitreous prevents the lens from slipping out of

[1] A model of the eye should be examined if possible.

[2] Anatomists generally use the latter term; physiologists call them *accommodation* muscles, from their function.

place. In front of the lens, between it and the cornea, is a transparent fluid called the *aqueous* humor. The fluid character of the aqueous enables the lens to bulge and flatten without much effect on the general shape of the cornea. Im-



xy. The optic axis.

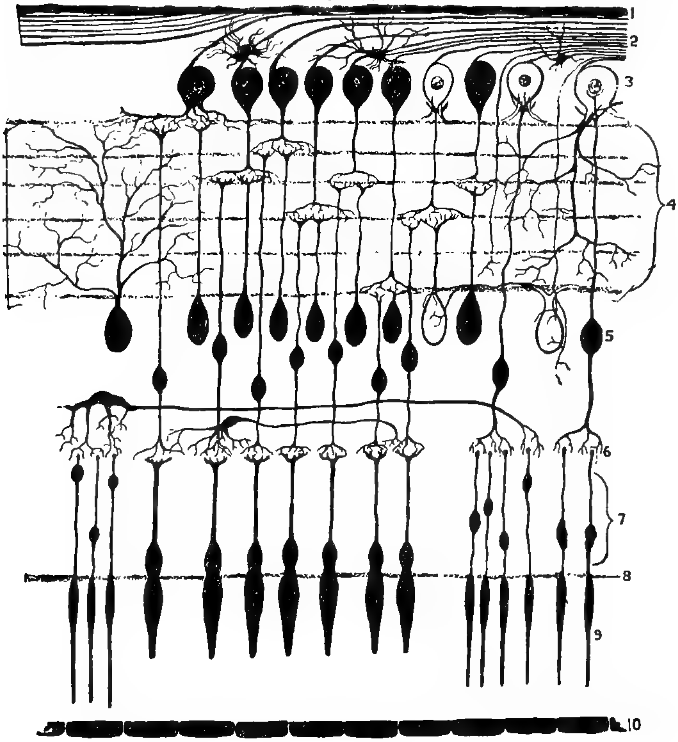
FIG. 30. — CROSS-SECTION OF EYE

Horizontal section through center of right eye viewed from above. Retina extends forward (toward lens) on each side as far as the notch. In *left* eye the optic nerve pierces the retina at the *right* of axis *xy*. [From Lickley, after Schaefer.]

mediately in front of the lens, between it and the aqueous, is another circular muscle called the *iris*, which cuts off the light rays entering from the side. The transparent opening in the center of the iris is called the *pupil.*

Back of the vitreous, on the inner rear surface of the eyeball, is the *retina.* [Fig. 31.] The retina is a net-work of cells

Interior of eyeball; vitreous



Exterior of eyeball; choroid coat

FIG. 31. — LAYERS OF THE RETINA

Schematic drawing of layers from the vitreous (interior of eyeball) to the choroid coat. Layers: (1) inner limiting membrane, next to vitreous; (2) layer of nerve fibers; (3) layer of nerve cells; (4) inner molecular layer; (5) inner nuclear layer; (6) outer molecular layer; (7) outer nuclear layer; (8) outer limiting membrane; (9) layer of rods (long, narrow) and cones (short, thick); (10) pigment cell layer. [Based on Piersol.]

and tissues of various sorts. It consists of ten distinguishable layers. The first of these (numbering from front to back) is a sort of retaining wall. The second layer consists of fibers of the optic nerve, which are distributed over the entire area of the retina. Beyond this (still toward the back of the eye) is a layer of nerve cells, and then several layers of cells and tissues which serve to temper the light and modify its intensity. The ninth layer consists of minute *rods* and *cones* which are peculiarly susceptible to stimulation by light. The tenth layer contains pigment cells which absorb any light which has escaped the intervening obstacles.

The rods and cones consist of elongated bodies arranged side by side and crowded closely together. The cones are shorter and thicker than the rods and taper to a point at the extremity situated toward the back of the eye. (The names will serve to identify each in the figure.) The rods are from 0.04 to 0.06 mm. in length, and from 0.002 to 0.004 mm. in diameter. The cones are from 0.03 to 0.04 mm. in length and from 0.004 to 0.006 mm. in diameter. At the central region of the retina only cones occur. Further out each cone is surrounded by a border of rods, while further still toward the edge of the retina (i.e., near the front of the eyeball) the cones become more rare and at the extreme periphery they are absent altogether.

Three points in connection with the retina should be particularly noted.

(1) Blind Spot: The optic nerve does not distribute its fibers on the outer surface of the eyeball in man or in other vertebrates. The whole mass of neurons *pass through* the outer coating at the back of the eye and are distributed about, forming the second layer of the retina. Consequently the light waves which penetrate into the eyeball pass among the optic nerve fibers and cells before reaching the rods and cones. The light waves do not affect the endings of these neurons directly; the terminals of the optic neurons are stimulated

only by the rods and cones. The stimulus passes through the retina from the inner surface to the outer in the form of light waves, and passes back again from the outer surface to the inner in the form of a nerve impulse. In the place where the optic nerve breaks through into the eyeball, the retina is entirely lacking. This place is called the *blind spot.*[1] [Fig. 32.]

(2) FOVEA: The center of the retina is directly behind the center of the pupil; a line joining them passes through the center of the lens and of the eyeball. The region about the center of the retina has a yellowish tinge and is called the *macula lutea.* At one point in the macula (near the center) there is a depression in the retina, in which the cones are crowded together much more closely than elsewhere. The result of this crowding together is that our discrimination of space is finer here than elsewhere. This region from its shape is called the *fovea centralis.* It constitutes the point of clearest vision.

FIG. 32. — MAP OF BLIND SPOT

Blind spot of the author's right eye. Drawn from two nearly identical records made in 1901 and 1902. F = fixation-point.

(3) PERIPHERY OF RETINA: The retina does not extend over the entire interior surface of the eyeball. It does not even extend as far front as the limits of the sclerotic. (The limits of the two may be compared in Fig. 30.) It is obvious that beyond a certain point the retina would have no use whatever, since the rays of light passing through the pupil (the opening in the iris) and lens reach only a limited portion of the inner surface; forward of this there is no retina.

[1] The blind spot of the right eye may be observed by turning the page upside down. Hold book six inches from the face, close the left eye and with the right fixate the word 'It' in the middle of the first line on page 154. Move the book slowly nearer and farther away, keeping the same fixation. The page number will disappear and reappear.

The two eyes not only coöperate, but in several ways they supplement each other. Our ability to estimate how far off an object is situated is due in part to binocular vision. Furthermore, the optic nerve breaks through the retina at different points in the two eyes, so that the blind spot of one eye corresponds to a region of rods and cones in the other, and no point in the field before us is lost.

Turning now to the motor mechanism of the eye. [Fig. 33.] The eye is held in place and moved by six muscles arranged in

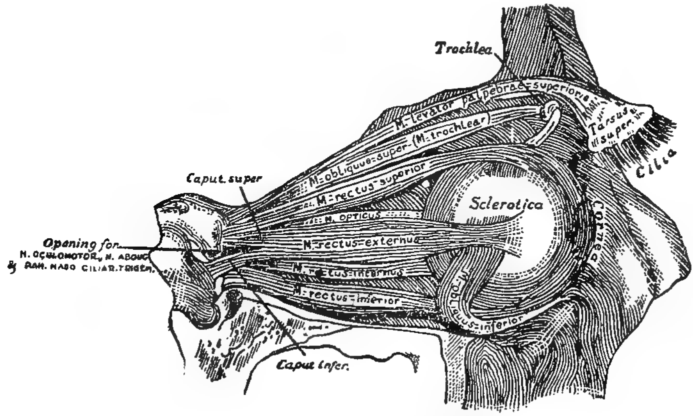


FIG. 33. — EYEBALL AND MUSCLES

Right eye from right side; external rectus muscle in central foreground. [From Smith and Elder.]

three pairs. One pair produce movements of the eye from side to side. These two muscles are called the *internal rectus* and *external rectus*. (The internal muscle is on the nasal side.) A second pair cause movements up and down. These are the *superior rectus* and *inferior rectus* muscles. The third pair pass obliquely across the eyeball, one above, the other beneath; they are called the *superior oblique* and *inferior oblique*. The oblique muscles assist in the up and down

movements,[1] and when two of the rectus muscles are working together the obliques hold the eyeball in position and prevent it from twisting circularly like the hands of a clock (torsion).

Physiology of the Eye. — The operation of the different parts of the eye has already been noted. We shall consider the process of visual stimulation as a whole. The rays of light which strike the eyeball further than about 4 mm. from the center of the pupil are cut off by the sclerotic and iris; when the iris is contracted even more of the rays are cut off. Only those rays which strike the pupil opening pass through into the interior of the eye. These light waves pass first through the cornea, then through the aqueous, the lens, the vitreous, and finally through the several layers of the retina till they reach the rods and cones and stimulate them. The stimulation is believed to be a chemical process.

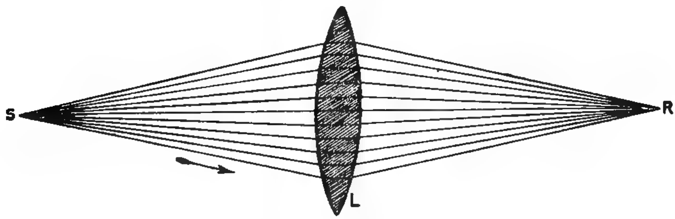


FIG. 34. — FOCUSING OF OBJECTS ON RETINA

When lens of the eye (L) is properly accommodated for the distance of a stimulus S which we are observing, all the light rays from S meet at a single point R on the retina. So for stimuli from other points above, below, to right, and to left of S, at the same distance. An inverted image of the object is thus focused clearly on the retina.

Owing to the convexity of the lens the rays are bent as they pass through it. The shape of the lens is regulated by the ciliary muscle, so that under normal conditions all the rays from any given point in the field meet upon a single point in the retina. [Fig. 34.] Thus when the ciliary muscle is properly adjusted each point in the surface or field which we are

[1] The recti do not pull the eyeball *directly* up and down, but if acting alone would turn it somewhat *inward* as well.

looking at furnishes a uniform homogeneous stimulus to one single point of the retina, so that the whole field of vision is clear and distinct. The projection of the objective field on the retina is upside down (inverted) like the picture on a photographic plate.

The nerve fibers are excited by the activity stimulated in the rods and cones. The resulting nerve impulses are transmitted separately along the fibers, which are grouped together into a bundle called the *optic nerve.* The optic nerve passes through the blind-spot opening of each eye, and the two optic nerves come together a short distance beyond this; their juncture is called the optic *chiasm.* Here the fibers from the inner (nasal) half of each retina cross over, while those from the outer half proceed along on the same side of the head. [Fig. 35.] It thus comes about that all the fibers from the left half of both retinas pass to a visual center in the left side of the cerebrum and those from the right half to a center on the right side.

Ciliary and Iris Reflexes. — If we look suddenly from near by to a greater distance, objects will be out of focus and will appear blurred; but the ciliary muscle immediately relaxes and a sharp impression is at once obtained. This adjustment is called *accommodation,* or uniocular focusing. When we look nearer, the ciliary muscle contracts, the lens bulges out, and the impression again is clear and sharp. In the normal eye the accommodation adjustment covers a range of distances from about 10 cm. (near point) to about 6 m. (far point) from the eye.

When the general illumination of the field is suddenly brightened the *iris muscle* begins to slowly contract; as it squeezes together the pupil becomes smaller, the amount of light admitted to the eye is decreased, and after a period the dazzling effect disappears. Similarly, when the field is darkened the iris muscle gradually relaxes, the pupil is enlarged, and objects begin slowly to appear in the twilight. This adjust-

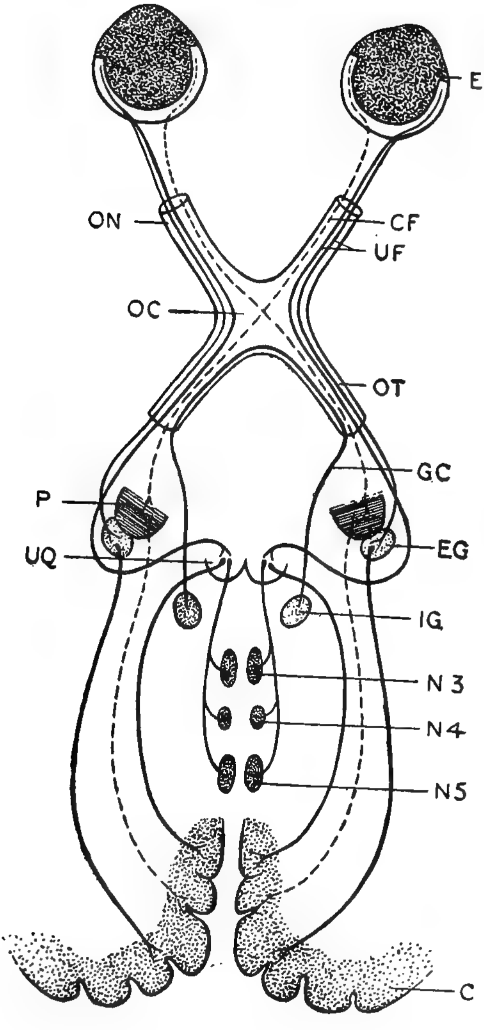


FIG. 35. — COURSE OF OPTIC NERVE

Showing juncture of the two optic nerves at chiasm, with crossed and uncrossed fibers, and their paths beyond.

E = eyeball; ON = optic nerve; CF = crossed fibers; UF = uncrossed fibers; OC = optic chiasm; OT = optic tract; GC = commissure of Gudden; P = pulvinar; EG = external geniculate body; IG = internal geniculate body; UQ = upper quadrigeminal body; N3, N4, N5 = nuclei of III, IV, V cranial nerves; C = cortex, occipital lobe. [Modified after Lickley.]

ment is called the pupillary reflex or *iris adaptation.* It prevents injury of the retina through too intense stimulation.

Eye Movements. — The ciliary and iris reflexes are motor processes which assist in visual reception. The movement of the eyeball as a whole is another motor process which regulates visual sensation. We noticed that the retinal elements are crowded closely together at the fovea, so that space discrimination is more acute. Objects are observed more precisely when they lie directly in front of the fovea.

By an inherited reflex mechanism the eye muscles act so that when the rays from a bright object (or an object especially observed) fall on a point toward the edge of the retina the eyeball quickly turns in such a way as to bring this object directly in front of the center of vision. That is, the eye rotates till it ' centers ' the object on the retina. This centering of an object is called *fixation.* If the point to be fixated lies below the center, the inferior muscles of both eyes are contracted; if above, the superior muscles; if the point lies to the right or left the external muscle of one eye and the internal of the other are contracted. If the object lies diagonally above and to the right, both the superior and external muscles of the right eye are contracted, and the superior and internal muscles of the left eye; and so for other diagonal positions.

In ordinary eye movements the superior muscles of the two eyes work together and so do the inferior muscles; the external muscle of one eye works with the internal of the other. But when we fixate from a point near the eye to a point farther away along the *same line* of regard, the external muscles of the two eyes work together, and conversely the two internal muscles when we alter our regard from a considerable distance to a point nearer by. The change of fixation from far to near (or the reverse) is called *convergence* or binocular focusing.

Visual Stimuli. — The light waves which serve as stimuli for sight are minute vibrations in the ether. There are two different types of physical vibration, *longitudinal* and *transverse.*

Longitudinal waves are those in which the particles move forward and back in the same line of direction as the wave movement. In transverse waves the particles vibrate from right to left or up and down — that is, at right angles to the direction of propagation of the wave. The transverse type is illustrated by the surface-waves of a body of water when a stone is thrown in. The particles of water at any point move up and down as the wave passes, while the wave of disturbance moves horizontally away from the starting-point. Light waves belong to the transverse class, while sound waves are longitudinal. The distinction, though important in physics, is of no great moment for psychology.

The ether waves form a series, extending from vibrations of very minute amplitude to those of very great amplitude. The long waves (those of great amplitude) do not affect the organ of sight. Some of these are classed as heat waves and affect other senses. Similarly, the very short waves do not act upon the retina, though they are capable of producing chemical effects on a photographic plate. The intermediate waves, from about 760 $\mu\mu$ (millionths of a millimeter) to about 390 $\mu\mu$, act upon the rods and cones of the retina and serve as visual stimuli.[1]

When sunlight or any mixed light passes through a prism, the waves are refracted. Short waves are bent more than long waves. If the waves after passing through the prism be projected upon a white surface the whole series is distributed over the surface so that each wave length falls on a different spot. [Fig. 36.] This orderly series of waves is called the color *spectrum*. The instrument for refracting and projecting is called a spectroscope.

All ether waves travel through the atmosphere at the rate of about 300,000 kilometers (i.e., 200,000 miles) per second. In any medium of given density a light wave travels always at the same speed, regardless of its wave length or intensity.

[1] The exact limits are difficult to determine.

In other words, the *speed of transmission* is not a variable factor. But the *number of waves* which reach a given point in a given period of time is a variable factor: it varies inversely with the wave length. Thus the length of the light wave which gives the bright line B in the solar spectrum (a certain

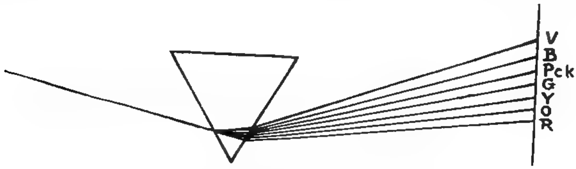


FIG. 36. — REFRACTION OF LIGHT

Mixed waves (traveling from left to right) are refracted at each surface of the prism; the shortest waves (violet end of spectrum) are bent most, long waves (red end) least. At any reflecting plane beyond the prism they form a spectrum.

red) is 687 $\mu\mu$; 417 trillion such waves strike the retina every second. Toward the other limit, the wave length of the G line (a certain violet) is 432 $\mu\mu$; 693 trillion such waves strike the retina per second.

Either the variations in wave length or the number of waves per second may be used as basis for measuring the vibration rate of the stimulus. These differences in light waves give rise to various modes of impulse in the optic nerve, and when the effect reaches the brain they produce different qualities of visual sensation. Each distinguishable color is caused by a specific rate (or range of rates) of light vibration. The so-called pure or white light observed in ordinary sunlight is a mixture of waves of all rates of vibrations. When no particular rate preponderates, mixed light waves give rise to the sensation of gray or white.

In addition to their differences in wave length, light waves may vary in *intensity* or amplitude of swing. An intense wave is one in which the particles are impelled with greater force and consequently vibrate further from side to side. An intense light wave acts more powerfully upon the rods and

cones than a less intense wave, resulting in a sensation of greater intensity. The phenomenon of intensity is observed centrally as degree of *brightness* in the sensation. An intense physical light wave causes a bright visual sensation; a wave of low intensity gives rise to a faint or dim sensation.

Quality and intensity are the two variables in the stimulus which determine the two chief characters of a sensation. Physical light waves vary also in duration and extensity. Both of these differences are observed by the human subject, but they are characters of sensation groups rather than of individual sensations, and are more appropriately discussed under the head of perception.

Characters of Visual Sensation: Qualities. — The qualities of visual sensation consist of two independently varying groups or series: (1) A series of *color hues* whose stimuli are waves of one single rate, and (2) a series of *grays*, whose stimuli are waves of many different rates combined. The gray series includes all shades of brightness; its extremes are the two sensation qualities called *black* and *white*.

The color qualities and the gray qualities may be combined in one sensation; this occurs when a stimulus consisting of a light wave of some definite length is accompanied by stimuli consisting of a general mixture of waves. Such combinations may occur in various proportions. For any given color a graded series of sensations may be obtained by increasing or decreasing the proportion of mixed light waves to single wave rate in the stimulus. This gives a third series called the *series of tints.*[1]

a. The Color Series; Hues. — Each pure color is due to stimulation of the retina by light waves of one single, definite length. Light waves form a continuous series, so that there are an infinite number of different physical wave lengths within the limits capable of stimulating the retina. But we do not distinguish an infinite number of colors. The sensa-

[1] Also a fourth series called *color-shades*, as will be explained presently.

tion produced by a 400 $\mu\mu$ wave is not observably different from the sensation produced by 410 $\mu\mu$. Each observably different color is called a *hue* or color tone. The number of noticeably different pure color qualities may be determined by observing two spectra, one above the other, or by color mixing.

Color mixtures are made by interlocking two or more colored disks, so that each occupies part of the front surface, and placing them on the axis of a wheel (color mixer), which is rotated very rapidly. [Fig. 37.] This gives an impression of one single color over the entire area; it is intermediate between the two hues.

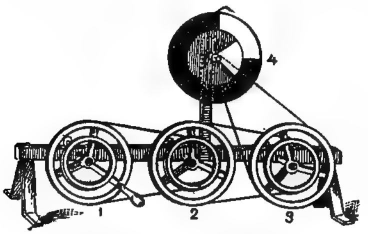


FIG. 37. — COLOR MIXER

Color disks are placed on axis of wheel 4. The mixer is rotated by turning a handle on circumference of wheel 1. By a series of belts connecting wheels 1, 2, 3, 4, the speed of rotation is greatly increased. [From Judd, after Rothe.]

To determine the hue which is just perceptibly different from the extreme red, we place a large disk of this red on the color wheel and over it place two smaller interlocked disks, one of the same red, the other yellow. Since the larger disk projects beyond the interlocked disks it can readily be compared with the mixture effect of the latter when the wheel is rotated. The proportion of the smaller disks is varied until the mixture is just perceptibly yellower than the larger standard disk. This procedure is continued, changing the colors used as need be, till we reach the other end of the spectral series (violet). We have then determined the number of perceptibly different color tones in the spectrum.

This does not exhaust the series of color qualities. If we mix violet light with red in various proportions, we obtain a certain number of new color qualities, which are known as purples. These purple hues are entirely different from any of

the hues which appear in the spectrum. Including the group of purples, the color series consists of about 150 to 160 distinguishable hues. The number varies in different individuals.

The pure color series is called the *scale of hues*. It extends from red, produced by the longest wave, to violet, produced by the shortest, the two ends being connected by the purples, so that the whole constitutes a circular series. [Cf. Fig. 39 B.] Not all of the distinguishable hues have received separate names. The popular terms red, yellow, etc., apply to groups of similar hues. Primitive man seems to have distinguished four such color groups, red, yellow, green, and blue. This is indicated by the fact that these names are so ancient that all trace of their etymological origin has been lost. Somewhat more recently certain immediate groups (orange, violet, etc.) have received distinct names derived from certain common fruits, flowers, etc. The spectral range of the best recognized groups is given in Table VIII.

TABLE VIII. — SPECTRAL LINES AND COLOR RANGE

Spectral Line	*Wave Length* $\mu\mu$	*No. of Vibrations* Trillion per second	*Color Hue*	*Range* $\mu\mu$
A	766.1	391.41		
Primal Red	——	——		
B	687.0	417.06	Red	760–647
C	656.28	456.91		
D_2	589.0	509.01	Orange	647–588
Primal Yellow	577	521	Yellow	588–550
E	526.96	569.03	Green	550–492
Primal Green	501	599		
F	486.14	616.82	Blue	492–455
Primal Blue	477	629		
G_1	432.58	693.19	Violet	455–390
H	396.84	755.62		

Visible Range: 760–390 $\mu\mu$, 399.55–768.87 trillion.

Limits of Color Change: 655–430 $\mu\mu$.

(Wave lengths from Houston, *Treatise on Light*, p. 473. Slightly different values are given in older tables, based on a less accurate correction factor. Primal colors from Titchener, *Exper. Psychol.*, Vol. I, Part I, p. 4. In many works the vibration numbers are given as "billions," following an old notation. There are *twelve* places after the decimal point.)

The average educated man of to-day uses only eight or nine names for pure color distinctions. These are (in serial order) red, orange, yellow, olive, green, peacock (or blue-green), blue, violet, and purple. The purple group is sometimes divided into carmine and magenta. Distinctions within any color group are designated by compound names (yellowish orange, reddish orange, etc.). Technical names have been coined for certain specific hues, but they are not frequently used except by painters and other specialists. The name *brown* is given to a group of impure yellows which are observed more frequently in nature than pure yellow itself. Other more or less familiar color names, such as maroon, baby blue, pink, etc., have been given to certain impure colors — either very light or very dark or highly tinted (unsaturated) colors.

Certain color hues appear to be more fundamental than others. Orange resembles red, but red and green are wholly dissimilar. The *number* of fundamental colors and the *exact hue* which is fundamental in each case have been subject to much discussion. Isaac Newton, following the analogy of the musical scale, selected seven colors which he called primary: red, orange, yellow, green, blue, indigo, and violet. Later, Thomas Young and Hermann von Helmholtz developed a visual theory based upon three *fundamental colors*, red, green, and blue (or violet). The selection was due to the fact that these colors, when combined in various proportions, will produce every other hue.[1] More recently Ewald Hering proposed a theory which recognizes four *primal colors* which are specific hues of blue, green, yellow, and red. This four-fold scheme seems to accord better with our observation of the ' obviously dissimilar ' colors. It is further supported by the following experimental evidence:

If the eye be fixated upon a point directly in front, and a color be moved gradually from near the fixation point out toward the periphery of the visual field, after a certain dis-

[1] See Appendix, "The Visual Process," p. 441.

tance the color changes to gray. For most colors, as the stimulus is moved toward the periphery the hue alters somewhat before passing into gray.[1] Thus a color which appears green when observed directly may become slightly yellowish or slightly bluish as it passes into the indirect field. But there are four specific hues which *do not alter* except as they gradually become gray. They are blue = 477 $\mu\mu$, green = 501 $\mu\mu$, yellow = 577 $\mu\mu$, and a slightly purplish red. These 'invariable' hues are the four primal colors.

b. The Gray Series; Shades. — Besides the series of color hues we observe a series of colorless visual qualities known as gray. These extend from the sensation of pure white to the sensation of black. The series is not circular like the colors; the two limits are extremely different, and there is but one way of passing gradually from black to white if we rule out color impressions altogether. By selecting a medium shade of gray and comparing it with a variable gray stimulus, we can determine how much black or white must be added in order to get an effect just noticeably different from our standard. The comparisons are continued in both directions until we reach the limiting white on the one hand and the limiting black on the other. About 700 shades of gray are distinguishable by the normal human eye.

While the gradations of gray are really due to differences of illumination, the sensation is accompanied by a qualitative change. It is not easy to recognize a quality difference between two neighboring shades of gray; but if we compare samples of gray near the two extremes of black and white the difference of quality is very noticeable.

Moreover, if a portion of the eye be stimulated for some time by white while the surrounding field is dark, and if the eye be then suddenly closed, it is found that the relations of the two portions of the field are reversed — what was white becomes black and the surrounding black becomes white. This

[1] An apparatus used in this experiment is shown in Fig. 40, p. 177.

'complementary' phenomenon (which appears in colors also) indicates that black and white are actually visual qualities.

The gray series is called the scale of *shades* or *brightnesses*; it constitutes an independent series from *hues* or *color tones.*[1]

A difficulty in explaining the gray series lies in the fact that black is not the result of any light stimulus at all; physically, it corresponds to absence of stimulation. Some psychologists seek to explain the phenomenon of black, which is a real sensation, by assuming that it is not due to any process in the retina, but to a process that takes place in the visual center of the brain. More probably, however, black is the result of a physiological process in the retina induced by actual stimulation by white in neighboring portions of the field.

c. Mixed Series; Color-Shades and Tints. — The various shades of gray may be combined with the various pure color tones. This gives rise to a vast number of new visual sensations. If we mix a pure red with a sector of white on the color mixer the result is a light or whitish red; if we mix the same red with a black sector we get a darker red. Both are variations in the *shade of the hue.* A graduated series from light red to dark red may be obtained by using the disk shown in Fig. 38 A. It forms the *color-shade* series for red. There is a color-shade series for each hue.

Now suppose we select a gray disk which is *neither brighter nor darker* than the pure red disk we are using and rotate the two on the color mixer. What is the result? We observe that the color does not become either brighter or darker.[2] But

[1] The division of visual impressions into a 'black-white' series and a 'color hue' series is based upon variations of the stimuli, not upon observed similarities and differences among experiences. Self-observation gives several alternative classifications. In heraldry, for example, yellow and white are grouped together as 'metals'; red, green, blue, and black are 'colors.' In popular anthropology the 'white' race is distinguished from the 'colored' races, which include yellow, red, and black.

[2] If we find that it has become darker this means that the gray selected is darker than our red; the error can be corrected by choosing a lighter gray or adding a little white.

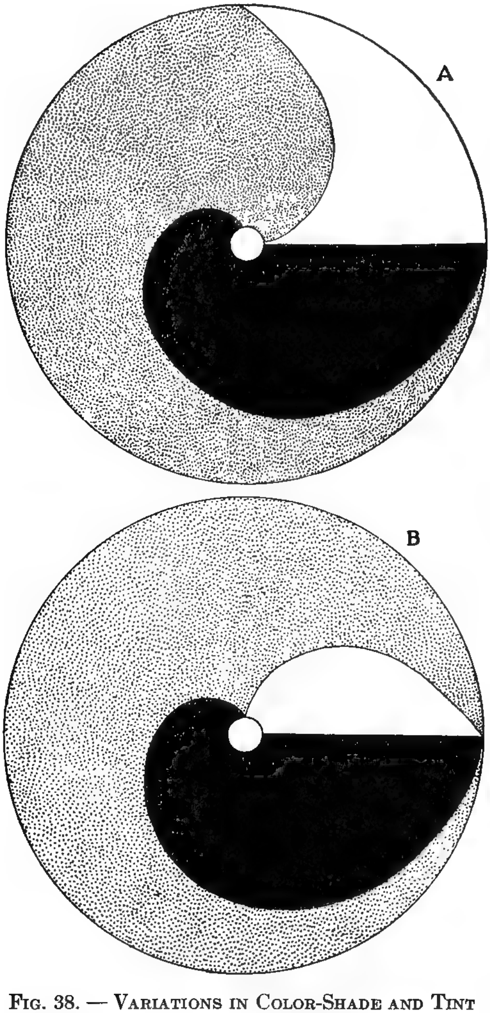


FIG. 38. — VARIATIONS IN COLOR-SHADE AND TINT

A. Color-shade series. — Disk for demonstrating gradual change from light red at circumference to dark red at center.

B. Tint series. — Disk for demonstrating gradual change from pure, saturated red at circumference to very unsaturated red ending in colorless gray at center. (Red is represented in both figures by the dotted surface.)

the visual sensation is decidedly different from that of the 'pure red.' The proportion between *color* value and *gray* value in the mixture is different. It is not a change in color hue nor a change in color-shade, but a third mode of color variation, called *tint*,[1] chroma, or saturation.

Whatever color we select, and whether its shade be light, dark, or medium, it is possible to add to it a certain gray of the same shade which will make it less saturated (less colored) without change of hue or shade. A graduated series of tints may be determined for any hue, beginning with the pure or saturated color and proceeding by least perceptible differences until we reach colorless gray. [Fig. 38 B.]

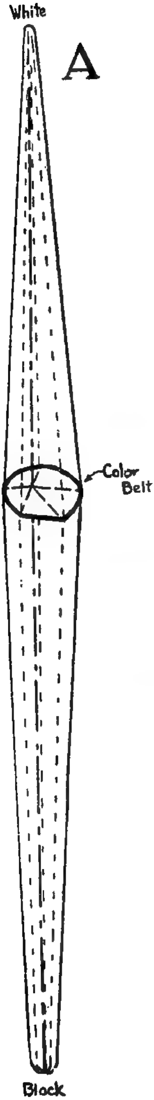
For simplicity we have supposed that the gray and the colors are of the same brightness; but it is possible to mix a color of one shade with a gray of quite a different shade — very much brighter or very much darker. There will then be a change of both color-shade and tint.

Number of Qualities; Color Spindle. — The total number of different visual sensations is determined by combining the number of pure hues, the number of gray-shades, and the average number of distinguishable color-shades and tints for a single hue. But if we multiply these factors together the product is too large. Very light and very dark hues have much fewer tints than the pure spectral hues; and at the extreme of brightness and darkness there is no variety of tint whatever — only white and black. It has been estimated that there are about 30,000 distinguishable visual qualities.

Since three independent variables [2] (hue, shade, and tint) enter into the production of visual sensations, the relations of the different qualities to one another must be represented graphically in three dimensions. The relations are shown

[1] The term *tint* is used by some writers to denote bright shades of a color hue.

[2] Gray-shade may be treated as the limiting case of color-shade — when the color value is reduced to zero.



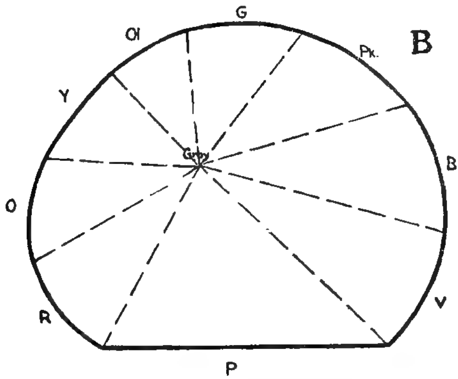


FIG. 39. — COLOR SPINDLE AND COLOR BELT

A. Color spindle; showing schematically the various distinguishable visual sensations, arranged according to shade (vertical directions), tint (radii from central axis) and hue (angles about axis). Gray series is represented by the central vertical axis. The purest hues (most saturated color tones) lie on circumference of the color belt. Relative proportion of shades, tints, and hues is indicated by relative number of units assigned to each. (Notice the preponderance of shade-units over others.)

B. Color belt, enlarged; showing relative number of distinguishable hues of each spectral color and of purple; relative saturation of the various pure hues is indicated by distances from central gray axis.

(The angle assigned in the figure to each color in the belt is somewhat conjectural; border-line hues might be classed under either component. The curve of the color belt is also schematic; exact data are not available. The proportion between circumference of belt and length of axis is fairly exact. The tilt of the belt in Fig. 39 A is indicated approximately.)

in Fig. 39 A. The schematic representation of visual qualities is usually called a color pyramid, but on account of the great length of the axis it is more properly termed a *color spindle.*

The series of colorless grays form the axis of the spindle, white lying at one extreme and black at the other. The pure colors, including the spectral hues and purples, are repre-

sented by a belt surrounding the gray axis and lying in a plane which cuts the axis near its midpoint. [Fig. 39 A, B.] The various tints of any given hue are represented along a line from the color belt to the axis, and the color-shades run parallel to the axis. The length of the axis is 700 units; the color belt is 150-160 units in circumference. The radii vary in length.

The shape of the spindle has only been roughly determined at present. The following points should be noticed: (1) The color belt does not lie in a horizontal plane. Yellow is distinctly lighter than green; violet is darker than the other spectral hues. In other words, the spectral belt is tilted upward at the yellow region and downward at the violet.

(2) The circumference is irregular in form. Violet and blue are the most saturated colors, then follow (in order) red, peacock, orange, green, and yellow. In other words, the circumference of the color belt lies furthest from the axis at violet, nearer at blue, and so on to yellow. The purples, being obtainable only by mixture, are less saturated than the spectral hues, especially at the midpoint between red and violet. They are represented in the color belt by a straight line.

(3) At the two ends of the axis the color differences fade away completely, so that the spindle tapers down to a point. The white end of the spindle is somewhat sharper than the black.

Every distinguishable visual impression, excepting those on the very outer circumference of the spectral belt and at the two poles (black and white) may be obtained by mixing (in proper proportion) two stimuli which lie on opposite sides of it in the color spindle. No *pure* spectral hue can be perfectly reproduced by a mixture of other hues; the mixture is always less saturated. The mixture of red and green, for example, will fall nearer the axis of the spindle than spectral yellow.

It is possible by combining spectral red, green, and violet in various proportions to reproduce any hue in almost its

purest (most saturated) form. By adding extreme white or extreme black (one or both) to the mixture any shade and any tint may be obtained. Hence we find the general law: "Every shade of gray, and every hue in every possible shade and in nearly every tint, can be produced by mixing black, white, pure red, pure green, and pure violet in various proportions."[1]

Certain additional relations are observed among visual qualities, which will be examined next.

Purkinje Phenomenon; Adaptation. — The relative brightness of different hues varies with the intensity of the stimulus. Under most conditions of illumination yellow is the brightest spectral color. If the illumination of the field be increased, yellow and red become brighter more rapidly than the other hues. On the other hand, if the illumination of the field be diminished, the hues which represent long waves darken more quickly than the short-wave colors. The difference appears most strikingly if we compare blue and red. The same shade of blue which appears darker than a given red when the general field is bright, appears brighter than this red in a faintly illuminated field. This variability in relative brightness of color hues is called the *Purkinje phenomenon*, from the first discoverer.

The Purkinje phenomenon is associated with adaptation to bright and dark general illumination. Part of the adaptation process is a result of the iris reflex. When the general field is bright, the iris muscle contracts, the opening or pupil becomes smaller, and less light is admitted. In faint illumination the iris relaxes, enlarging the opening and admitting more light.

In addition to this muscular adaptation, a change of condition occurs in the retina with changes of general illumination. This is attributed to a substance in the retina called *visual purple*, which is affected by light. In bright illumination

[1] For most mixtures only three of these or fewer are required.

the visual purple is modified and produces slight differences in the color hue and greater differences in the brightness component. On this account the relations of colors, both as to hue and shade, vary in daylight and twilight. At the center of the retina (where no rods are present) this difference does not appear.

Adaptation for specific hues occurs when the general field is tinged with that hue. This is observed if we put on colored glasses. With green spectacles the whole field at first appears tinged with green. After a time this tinge disappears and the field appears normal, though certain hues are altered from their ordinary appearance, and red objects appear gray.

Complementaries. — If a disk of yellow cardboard and a disk of blue be fitted together so as to give a circle half yellow, half blue, and this be rotated rapidly on a color mixer, the two

TABLE IX. — COMPLEMENTARY COLORS

Standard Color	*Wave Length*	*Complementary Color*	*Wave Length*	*Relation of Wave Lengths*
Red	656.2	Green-blue	492.1	1.334
Orange	607 7	Blue	489.7	1.240
Gold-yellow	585.3	Blue	485.4	1.206
Gold-yellow	573.9	Blue	482.1	1.190
Yellow	567.1	Indigo-blue	464.5	1.221
Yellow	564.4	Indigo-blue	461.8	1.222
Green-yellow	563.6	Violet	433.	1.301

[From Ladd and Woodworth.]

will neutralize each other wholly or in large part. If we select a certain specific hue of each and mix them in various proportions, we will at some point find a mixture in which no color effect whatever is observed; the disk appears as a plain gray surface. For a given yellow, one and only one blue can be found which yields this effect. This yellow and this blue are called *complementaries*. For every color hue in the series, including the purples, one and only one complementary exists. [Table IX.] Black and white are treated as complementaries for reasons that will appear presently.

After-Sensations. — If we fixate the eye for some time upon a very bright color and then look quickly at a plain gray surface, the portion of the retinal field where the color appeared will give a sensation of complementary color. Thus if we fixate a bright blue circle the after-effect is a yellow circle surrounded by a faint tinge of blue. The same effect is observed if we close the eyes after observing a bright color. Such an after-effect is called an *after-sensation*.[1] It is due to fatigue of the stimulated retinal area for the given color. White gives rise to a black after-sensation, and conversely; for this reason they are considered complementaries. The degree of brightness and the period of fixation necessary to obtain an after-sensation vary greatly among different individuals. The vividness and duration of the phenomenon may be increased by practice.

If a practiced observer fixate a bright blue circle and then look quickly away, he will notice that the sensation of blue continues for a short time (part of a second) on the given region of the retinal field before the complementary appears. This effect is called a *positive* after-sensation. The complementary effect which follows is a *negative* after-sensation.

With practiced observers and under very intense illumination the negative after-sensation may last for many seconds. If the fixation on the gray surface be maintained without winking, the negative after-sensation fades slowly away and may be succeeded by a second positive after-sensation. Occasionally a second negative follows this, and even longer alternating series have been reported. The phenomenon may be strengthened by winking the eyes vigorously. The first positive after-sensation is due to inertia of the retinal processes; the first negative and all succeeding after-sensations are due to fatigue.

White and black act in very nearly the same way as colors

[1] It is often called an after-image; this name is misleading, as the impression is really a sensory, not an ideational process.

in respect to positive and negative after-sensations. Where a bright field is observed containing several different colors and grays, all the colors and grays reverse, but not always simultaneously; the bright colors and white shift first, and the outlying portions of a bright area may reverse before the central portions. The after-sensations of the darker portions of such a field disappear before the brighter after-sensations.

Contrast. — Complementary effects may be brought about under certain conditions without moving the eye. If we place on a mixer a disk containing a ring of black and white surrounded by a uniform color (e.g., blue), when the disk rotates the black and white ring is not seen as gray, but is tinged with the complementary (yellow) of the surrounding color. A similar effect is noticed in the Meyer pattern. This is a checker-board of small green and gray squares covered with thin tissue paper. When we observe the pattern through the tissue paper the colored squares appear green, but the gray squares have a salmon tinge. When the tissue is removed the salmon effect disappears, but it may still be faintly noticed around the edges of the gray squares if the eyes are not rigidly fixated. The appearance of the complementary effect *without eye movement* is called *simultaneous contrast.* The complementary color which appears around the borders when the eyes wander is a negative after-sensation. It is called *successive contrast.*

Peripheral Vision. — A greater number of hues are distinguished near the center of the retina than farther out toward the periphery. Each hue gradually fades into an unsaturated tint as the color stimulus passes from center to periphery. At the periphery all the hues disappear and only distinctions of gray are observed unless the stimuli are very bright.

The limits of the retinal field for each color may be explored by means of the *perimeter.* [Fig. 40.] If we explore the entire field, above and below, right and left, and in diagonal directions, it is found that the shape of the color zones is irregular.

They vary considerably for different hues. In most persons the field for green is far more limited than for other hues. [Fig. 41.]

In the retina the number of cones decreases from the center, where there are only cones and no rods, to the periphery, where there are no cones at all. It has therefore been supposed by some writers that the cones are receptors for color stimuli, and the rods for gray (mixed) stimuli. The fact that the cones are larger and apparently more differentiated than the rods gives support to this view, but the conclusion is not universally accepted. According to another view, the cones are receptors for 'daylight' vision, while the rods are receptors for 'twilight' vision, that is, for dim illumination of the field. The absence of color sensation at the periphery is one of several peculiar phenomena which make it difficult to formulate a satisfactory explanation of the visual process.

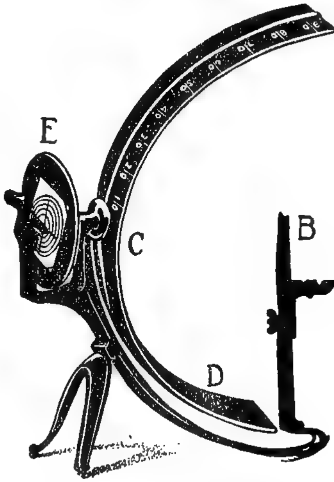


FIG. 40. — PERIMETER

Observer's chin is placed on rounded chin-rest A, which is so adjusted that one eye is directly over semicircular top of rod B, other eye being closed. A small hole through the axis at C serves as fixation point. Color stimulus is moved along one circular arm, D, of the perimeter toward or away from center, on a carriage. The arms rotate, so that all portions of the visual field can be explored. On far side of plate E (which rotates with perimeter arms) is fastened a disk, ruled radially and circularly to represent 'latitude' and 'longitude' from center of vision. Experimenter records the readings on this disk, which is hidden from observer by E. [From Judd, after Meyrowitz.]

Color Blindness.—A still more perplexing phenomenon is *color blindness.* Certain individuals, otherwise normal, fail to distinguish color hues in the same way as the average human being. They are not merely unable to dis-

criminate *fine* differences of hue (red from orange-red, etc.); but they may be quite unable to distinguish between certain

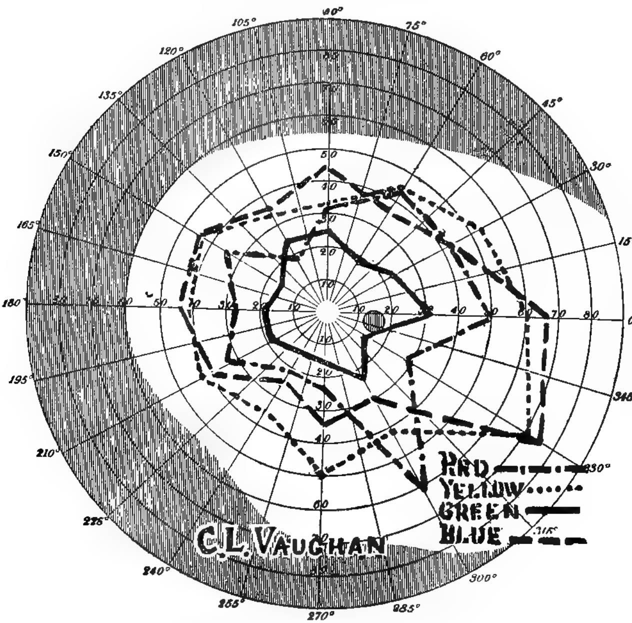


FIG. 41. — COLOR ZONES OF RETINA

Limits at which four colors disappear in passing toward periphery, determined for radii 30° apart. Right eye.

hues which lie far apart in the spectrum, such as red and green. Color blindness is either total or partial.

Total color blindness is inability to distinguish between any colors whatsoever. To a totally color-blind individual the world appears like a photograph — a collection of gray shades without coloring. This condition is called *monochromatism.*

There are three fairly distinct types of partial color blindness, which are popularly called red, green, and blue blindness. The first two, which are the most common forms, are some-

times grouped together under the general name of red-green blindness. A red-green blind individual may be unable to distinguish between the colors of the flowers and leaves of a red geranium. He will confuse a red shawl with a green shawl if the two are of about the same degree of brightness. He will distinguish readily, however, between bright red and dark red, and between bright red and dark green. The difference between the two types of red-green blindness is observed when the subject is tested for all the spectral hues and the brightness of these colors is compared. Individuals of the red-blind type are not sensitive to the extreme reds of the spectrum, and the region of maximal brightness is displaced towards blue-green; hence, red looks black and green a light gray to them. Individuals of the green-blind type are sensitive to all the colors, but see reds and greens as yellow. To the red blind the spectrum appears dark in the red region, then yellow — gray — blue; to the green blind it appears as yellow — gray — blue. The former type is called *protanopia*, the latter *deuteranopia*, from the order in which the cases were first classified.

A third type of partial color blindness occurs in a few instances, where the individual is unable to distinguish between blue and yellow; this is called blue blindness or *tritanopia*. The spectrum appears as red — gray — green, with the violet end dark. As this type is fairly common in certain diseased conditions of the eye, many writers are inclined to classify all such cases as pathological.

In partial color blindness of any type the entire series of hues which the subject can distinguish may be produced by mixing two colors, instead of three as in the normal eye. Partial color blindness is therefore called *dichromatism*. Normal color vision, as we noticed, requires three distinct color components to produce all the hues, and is called *trichromatism*.

The brightness or shade-value of any color may be deter-

mined by comparing it with gray. If a disk of a certain red hue be placed on the color mixer and a smaller disk, part white, part black, be set on the same axis, the proportion of white and black may be varied till the gray disk appears of equal brightness with the surrounding color. The proportion of white to black thus determined is the measure of brightness value for the red which we are examining. This proportion is called the *brightness equation* of the color. The brightness equations for various hues in the normal eye are different from those of the protanopic or red-blind eye, but practically the same as those of the deuteranopic or green-blind eye. It is thus possible to distinguish the several types by tests in which colors of different brightness are compared. A bluish red and a bluish green which would appear equally bright to the normal eye, though differing in color, would appear to the deuteranope as grays of equal brightness; to the protanope they would appear as a very dark gray and a very light gray, respectively.

Color blindness in one form or another is present in about four per cent of the human race. Partial color blindness is a heritable character and is in some way linked up with sexual characters. Thus if a color-blind man marries a color-normal woman their children have normal color vision, but the sons of their daughters are likely to be color blind. In other words the character is transmitted to the male grandchildren through the daughters, in whom it is latent. Color blindness is far more prevalent among men than among women. Apparently females are color blind only when color-blind males marry females in whom color blindness is latent.

Theory of Visual Qualities. — Several attempts have been made to explain the complex relations and peculiarities observed in visual qualities. What is required is to discover a physiological process, or rather group of processes, of such nature that when they are stimulated the various phenomena will occur through their interworking. It has been difficult

to picture a set of processes which would account for *all* the observed facts.[1]

The most satisfactory explanation so far suggested is the theory devised by Christine Ladd-Franklin. According to this view visual sensations originally comprised only shades of gray. It is assumed that there exists in the rods and cones a certain substance called the color molecule, which when stimulated gives rise to sensations of gray and white. In the course of evolution the color molecules in the *cones* become differentiated into two components, one part exciting a neural process which yields sensations of blue, the other yielding sensations of yellow. Later, the *yellow* component becomes differentiated again into two components, one of which excites a process yielding sensations of red, the other a process yielding green.

Certain specific wave lengths affect each one of the components, giving the sensations of primal red, green, and blue. A certain other specific wave length stimulates the red and green components in such a way as to excite the process belonging to the ‘ older ’ yellow component; the resulting sensation is primal yellow. All other wave lengths stimulate two of the components and give rise to an intermediate color. When mixed waves strike the cones the resulting sensation is gray (or white), which is the original visual process of the undifferentiated molecule. The color molecules in the rods are not differentiated, and hence they always yield gray.

This genetic visual theory recognizes the existence of three *fundamental* colors, red, green, and blue, out of which all other effects arise by combination; it also recognizes the four *primal* colors, each of which is unlike the other three. The chief difficulty of the theory is to account for the sensation of black.

Visual Intensity. — In sight the intensity of sensation is closely bound up with the white-black quality changes, and many of the intensity phenomena have been examined in pre-

[1] See Appendix, "The Visual Process," p. 441.

ceding sections. The Purkinje phenomenon and twilight adaptation may be treated as intensity relations. Pure intensity relations may be investigated by measuring least perceptible differences of brightness in the gray series. This is determined by comparing a certain gray taken as standard with a graduated series of slightly lighter or darker grays.

The least perceptible difference at the white end of the scale may be determined by means of a *Masson disk,* which presents

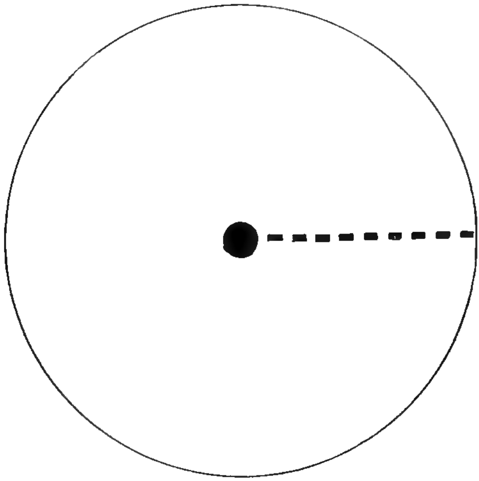


Fig. 42. — Masson Disk

a white surface with a single broken black line of uniform thickness. [Fig. 42.] When this disk is rotated the black and white mix, giving a series of concentric rings, which become fainter towards the circumference. The last distinguishable ring indicates the proportion of black which, mixed with white, gives a sensation just perceptibly darker than white.

The least perceptible brightness at the dark extreme may be determined as follows: The observer is placed in a dark-room with blackened walls. On a black surface before him

a pencil is fixed upright. A light of standard brightness is moved slowly toward the pencil from a distance till the subject just observes the shadow cast by the pencil. The sensation of faint light discriminated from the shadow, is called the *least perceptible brightness*. Certain visual processes occur in the retina, however, even when no stimulus is present; so that the experiment really measures the brightness of objective stimulation which is least perceptibly different from the eye's 'own light.' According to S. P. Langley the energy of the light which produces the least perceptible visual sensation under most favorable conditions is 0.000,000,03 ergs.

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PRACTICAL EXERCISES:

Test and describe your after-sensations of color.

Describe your experience of visual adaptation in going suddenly from a very light to a very dark room and vice versa.

Cut strips of colored papers (R, Y, G, and B) 3 inches long, $\frac{1}{4}$ inch wide; paste each on a white card. Stand card on table in good light; walk backwards till color becomes indistinguishable. Repeat for each color. Report distance for each, and any other phenomena observed. (Describe experiment in full.)

CHAPTER X

THE SENSES (*continued*)

2. HEARING (AUDITION)

Structure of the Ear. — The receptor organ for hearing is the *ear;* but technically the ear includes much more than the peculiar-shaped shell which projects from the side of the head. The outer shell serves merely to gather the stimuli and direct them into the channel which leads to the inner ear. The receptor proper is a complex structure within the skull.

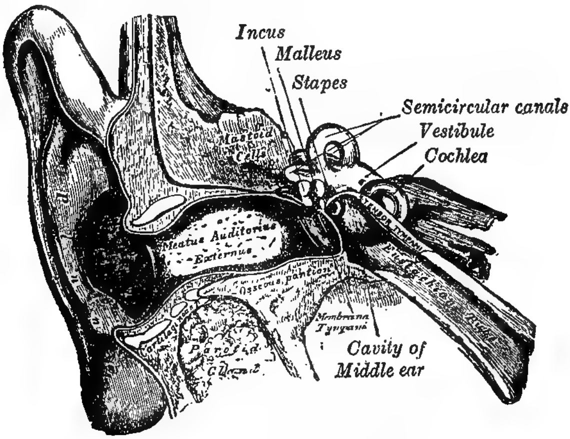


FIG. 43. — CROSS-SECTION OF EAR

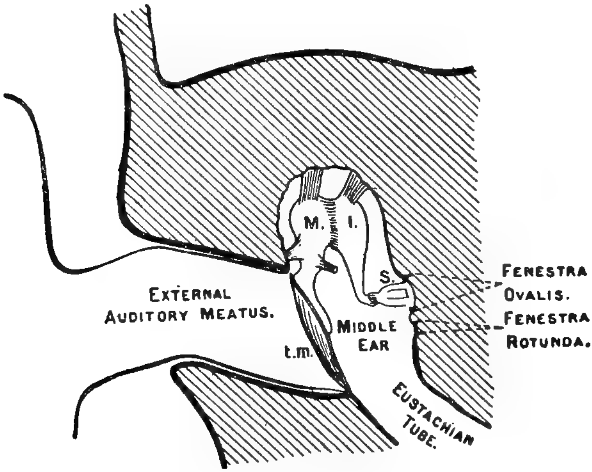
Vertical section of right ear through meatus and tube, viewed from front. Oval window lies behind the stapes; round window behind initial letter T of word 'tensor' at base of cochlea. [From Lickley.]

The auditory organ is divided into the outer ear, middle ear, and inner ear.[1] [Fig. 43.] The outer ear consists of the shell (*concha*), together with the tube (external *meatus*)

[1] A model of the ear should be examined if possible.

which passes through an opening in the skull and terminates in a vibrating membrane called the ear-drum (membrana tympani, *tympanum*).

The middle ear lies in the head beyond the ear-drum. It consists of a cavity bounded by the drum on one side and a



M. Malleus. I. Incus. S. Stapes. t.m. Tympanic membrane.

FIG. 44. — DIAGRAM OF MIDDLE EAR

Showing position of the three bones and two windows. [From Lickley.]

bony wall on the other; in this wall are two apertures, called from their shape the *oval window* and *round window*. Each window is fitted with a vibrating membrane. The middle ear cavity extends inward and downward as a narrow tube (*Eustachian tube*), which opens into the back of the mouth. The distinctive features of the middle ear, besides the two windows, are a chain of three small bones called the *hammer*, *anvil*, and *stirrup*. [Fig. 44.] The hammer bone (malleus), shaped like a rude primitive hammer, is attached at the handle end to the center of the drum, and at the middle is grasped and

held in place by a tendon. The head of the hammer fits into the anvil bone (incus). (Note that the hammer is operated by vibrations of the drum at the *handle* end — the middle is rigid.) The anvil attaches to the arch of the stirrup bone (stapes), whose two ends are attached to the membrane of the oval window. When the drum membrane vibrates to and fro, the vibration is transmitted through this chain of bones to the oval window and causes the membrane of the window to vibrate back and forth.

The inner ear or *labyrinth* is a very complicated cavity, only part of which serves the auditory function. The dorsal portion contains the semicircular canals and their appendages, which act as receptor for the static sense. [See page 211.] The portion of the labyrinth concerned with hearing lies in front of this (ventrally), immediately inside the two windows. It consists of (1) a cavity called the *vestibule,* which is formed by two rounded protuberances called the utricle and saccule; (2) a spiral structure resembling the shell of a snail and called the *cochlea.*

The inside of the cochlea forms a spiral chamber which is divided lengthwise by partitions into three separate tubes filled with liquid. The three tubes lie side by side and follow the spiral windings from the base of the cochlea to its apex. [Fig. 45.] (1) One of these tubes, called the *scala vestibuli,* leads from the oval window. When the window vibrates back and forth a series of waves are transmitted the length of the scala vestibuli. (2) The second tube, called the *scala tympani,* terminates below at the round window. At the apex of the cochlea the two scalæ are connected. Thus the vibrations from the scala vestibuli pass into the scala tympani at the far end and travel downward through it, passing out in vibrations through the round window. (3) The third tube, somewhat smaller than the others, is called the *cochlear duct.* It is separated from the scala vestibuli by the *membrane of Reissner,* and from the scala tympani by the *basilar mem-*

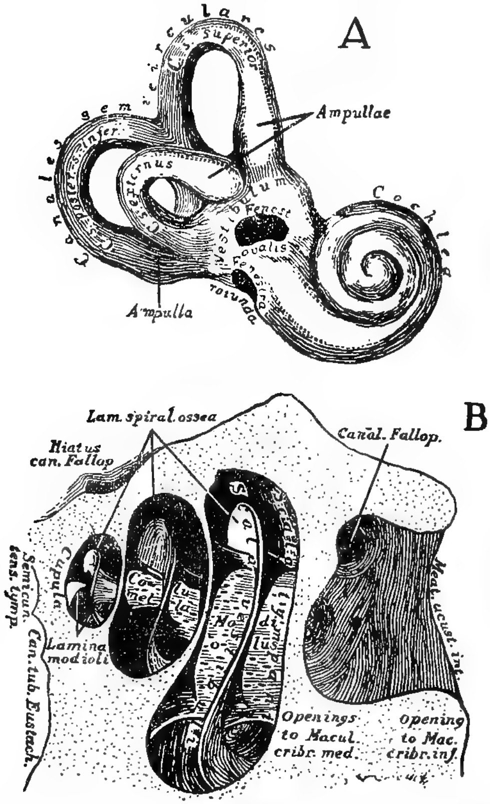


FIG. 45. — LABYRINTH AND SECTION THROUGH COCHLEA

A. Right ear; perspective in same general plane as Fig. 43. Semicircular canals at left, cochlea at right; between them the two windows.

B. Longitudinal section of cochlea, showing spiral windings of the scala tympani and scala vestibuli. The cochlea duct (not shown) lies between two membranes, which form a continuation of the spiral lamina (Lam. spiral. ossea) just this side of the plane of section. [Both figures from Smith and Elder.]

brane. In a small canal within the cochlear duct, and attaching to the basilar membrane, is a system of rods and hair cells called the *organ of Corti.* [Fig. 46.] They connect with fibers of the auditory nerve and are the specific receptors for audi-

tory stimuli. The hair cells and rods of Corti are attached at the ends in such a way that they vibrate when waves pass through the cochlea. They gradually increase in length from the base to the apex of the cochlea. One or another is affected according to the wave length of the vibration, just as a tuning fork of given length is set in vibration by one particular sound and not by others.

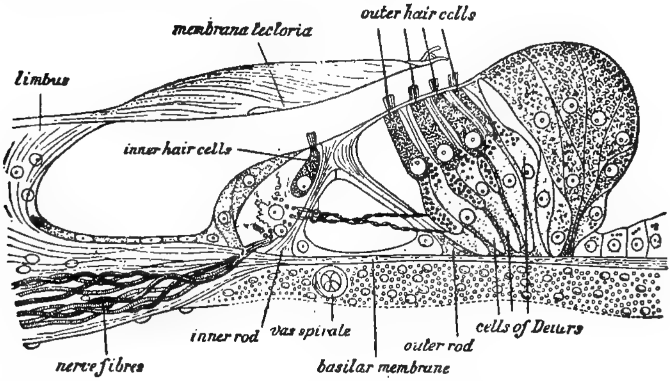


FIG. 46. — ORGAN OF CORTI

Section perpendicular to direction of windings of the scalæ. Rods (or fibers) of Corti are designated 'inner rod,' 'outer rod.' The rods and hair cells become longer in successive sections toward apex of cochlea. [From Lickley, after Retzius.]

Auditory Stimuli. — The auditory stimuli consist of molecular vibrations called *sound waves*. Sound waves are produced by vibrations of the molecules composing solid, liquid, or gaseous bodies and by to-and-fro vibrations of strings and membranes.

For practical purposes we may divide the sources of sound waves into three classes: (1) Vibration of air molecules, generated in organ pipes and other wind instruments. (2) Molecular vibration of solids, produced by striking a bell, steel bar, xylophone. (3) Mass vibration of flexible solids such as tuning forks, stringed instruments, and drums. A tuning

fork is attached at one end and vibrates freely at the other; a violin string is attached at both ends and vibrates freely in the middle; the membrane of a drum is attached all around the edges and vibrates at the center. The vibrations of solids, whether molecular or mass, are usually transmitted through the air and reach the ear as air vibrations. They may be transmitted through the skull to the ear-drum if a vibrating tuning fork is pressed to the head.

Sound waves are longitudinal vibrations; that is, the particles move to and fro in the same line as the propagation of the wave itself. In this they differ from light waves, where the individual particles move back and forth at right angles to the line of wave propagation. [See page 161.] Looking along the line of wave motion at any moment there is first a region of compression, gradually passing to a region of rarefaction of the particles, and so on.

The speed of propagation of a sound wave is uniform for any given medium. The denser the medium the slower the speed of transmission. In air the sound waves, whatever their character, travel at the speed of 332.4 meters (about 1000 feet) per second. Sound waves, like light, vary in two respects, wave length (rate), and amplitude (intensity).

The length or rate of a sound wave is not a matter of its speed (which is uniform); it depends upon the distance between successive 'pulsations' along a given path. We may measure either (1) the number of compressions which reach a given point each second; or (2) the distance from one point where the particles are at their maximum compression to the next point where the same condition (phase) exists at the same instant. These two measures vary inversely with each other. The greater the number of sound waves in a given time, the shorter are the individual waves; if the length of each wave is increased, the number of waves is lessened.

The sound waves form a continuous series extending from very long to very short; but not all of these waves stimulate

hearing. The human ear does not respond to sound waves more frequent than about 30,000 per second,[1] nor to those less frequent than about 16 or 12 vibrations per second. Between these limits every length and frequency of sound wave affects the normal human ear and gives rise to an auditory sensation. Not all of the infinite number of rates between 12 and 30,000 are distinguished as different qualities. We cannot, for example, detect any difference between the sensation due to a wave of 12,000 and that due to a wave of 12,010 vibrations per second.

Physiology of Hearing. — The physiological processes concerned in hearing were partly described in our examination of the ear. When the sound wave reaches the shell of the ear it is caught and transmitted through the meatus and strikes the ear-drum. The drum is set in vibration according to the rate and intensity of vibration, and the chain of bones (hammer, anvil, and stirrup) vibrate to and fro, the stirrup causing the membrane in the oval window to vibrate. This in turn causes the liquid which fills the cochlea to vibrate at a certain rate and intensity, and this vibration is transmitted up the windings of the scala vestibuli and down the scala tympani. During its passage it affects some one of the hair cells or Corti rods in the cochlear duct, which connect with fibers of the eighth cranial nerve; the vibration of these cells serves as stimulus, starting a nerve impulse in one or more of the fibers, which is transmitted along the nerve to the auditory center in the brain.

Were it not for the flexible membrane in the oval and round windows the liquid in the cochlea would not take up the vibrations from the middle ear. The connection between the middle ear and the mouth by means of the Eustachian tube prevents permanent loss of hearing from very intense stimuli. A very intense sound wave drives the ear-drum back so far that it adheres to the further wall; in such cases by swallow-

[1] Wundt gives the upper limit as 37,000–40,000.

ing we force air from the mouth through the Eustachian tube into the middle ear, which drives the drum back into its normal position. The action of the stimulus upon the receptor is a mechanical (vibrating) effect — not a chemical process as in sight.

In man there is no motor function specifically attached to hearing. In some vertebrates the outer ear is furnished with muscles which serve to move the shell to right or left, enabling the animal to focus upon a sound just as we focus the eye upon a bright light. A rudimentary muscle for moving the ear still persists in man, but it is seldom under voluntary control and in any case the movement does not assist in hearing. Our only means of focusing sound is by moving the whole head.

Characters of Auditory Sensation: Qualities. — Differences in rate of physical sound waves give rise to different qualities in auditory sensations. Just as in visual sensations, we find a series of auditory qualities due to various single vibration rates, and a separate quality due to mixed rates of vibration. The former are called *tones*, the latter *noise*. Sensations of noise are not so distinct from tones as the corresponding visual impressions. A series of noise qualities may be distinguished, but their character is that of the dominant tone. Noise differs also from gray sensations in that it is characteristically unpleasant.

Tones (Pitch). — The different rates of vibration of sound waves give rise to a series of tone qualities, called *pitch*. Low vibration rates (few waves per second) cause sensations known as *deep* tones; high vibration rates (many waves per second) give rise to *shrill* tones.[1]

Some individuals are able to recognize any tone, and to compare its pitch with that of other tones heard some time before. They will report that the standard pitch of a piano in one

[1] They are sometimes called *low* and *high* tones respectively, but these terms are liable to be confused with soft and loud, which represent intensity differences.

house is slightly deeper than that of a piano in another house, or that a tune is sung ' in a higher key ' to-day than yesterday. This is called recognition of *absolute pitch.* This ability is not possessed by many. Ordinarily tones are not ' individualized ' as colors are. Most persons find difficulty in identifying any specific tone after a lapse of time; consequently the tones have not received popular names corresponding to red, blue, etc.

The tone produced by stimuli of 256 vibrations per second is adopted in scientific works as the *standard pitch.* It is called c^1. Other tones are defined by their relation to this standard.[1]

The tone corresponding to 512 vibrations is observed to be closely related to c^1. It is called c^2. Similarly, the tone corresponding to 128 vibrations stands in the same relation to c^1 as c^1 to c^2. It is called c. The general relation of two to one is called the *octave* relation; it is the relation between any tone and the tone produced by twice or half its number of vibrations.

The human ear is very acute at distinguishing relationships among tones. This ability is known as *relative pitch,* and the relation is called an *interval.* Intervals are measured by the ratio of vibration rates of the two tones which compose it. In modern music only a few different intervals are used. They are all based upon simple numerical ratios between the number of vibrations of the two tones. The octave ratio is 1 : 2; fifth 2 : 3; major sixth 3 : 5; major third, 4 : 5, and so on to the minor second 15 : 16 — the least simple ratio in common use.[2] These relations have been elaborated into a series of tones called the *musical scale.* [Fig. 47.]

The musical intervals bear no relation to the *least observable* differences of pitch. While the smallest tone interval used is the semitone, whose ratio of vibration is 15 to 16,

[1] In tuning instruments for musical performances a different standard is used, called *concert pitch ;* in this $c^1 = 264$.

[2] The names *sixth, third,* etc., are based on the number of keys covered by the interval on the piano or other fixed instrument.

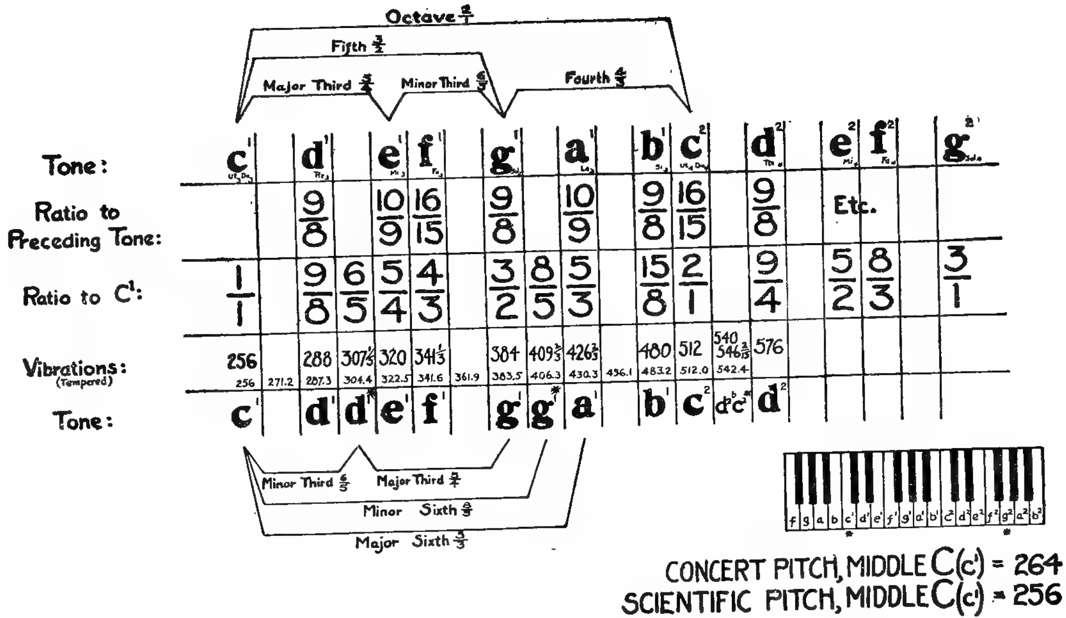


FIG. 47. — MUSICAL INTERVALS

Table of tones and intervals composing the modern musical scale, showing ratio of vibration numbers.

the threshold of difference between tone sensations in most cases is far less. At 256 vibrations, which is in the medium range of hearing, we can distinguish normally between tones of 256 and 256.5 vibrations per second, a difference of $\frac{1}{2}$ vibration. In the region of very shrill tones the threshold of difference is much higher; in other words, the discrimination is less fine. In very deep tones discrimination is also less fine relatively than in the medium range. The trained human ear can distinguish altogether about 11,000 differences of pitch.

Overtones and Timbre. — When a single tone is sounded, it is usually accompanied by subsidiary vibrations of twice, three times, four times, etc., the number of vibrations. If we pluck a violin string it will vibrate not only as a whole, but also in half lengths, thirds, quarters, or fifths, etc., according to the place where we pluck it. These subsidiary tones fuse with the original tone (the fundamental) and are distinguishable only after considerable practice. They are called *overtones*. A fundamental with its overtones constitutes a *simple clang*.

In simple clangs the overtones often fuse so completely as to be indistinguishable; the clang appears as a simple sensation. But even though the overtones are not distinguished they alter the total effect. This is observed when the same tune is played first on the piano, then on a violin, a cornet, etc. Different instruments are characterized by various sorts of overtones, so that we distinguish not merely the tune, but the kind of instrument. The specific character of a clang due to its overtones is called its *timbre*. Each kind of instrument has its own peculiar timbre; the human voice has a great variety of overtones and each individual voice has a timbre of its own.

Combination Tones and Compound Clangs. — When two tones are heard at the same time they combine in such a way that their identity is partly lost. This combination effect is an instance of *fusion*. In tonal fusion the tones do not merge

together completely; with practice either of the components can be discriminated from the total impression. Tonal fusion is a different kind of summation process from that which occurs in sight. When different colors stimulate neighboring parts of the retina the sensations are distinct and the only modification which occurs in the combination is the contrast effect; this variety of combination is *colligation* (ch. viii). Fusion and colligation are due to different ways in which the separate nerve impulses are summated in the centers.[1]

When two distinct tones are sounded together, it is possible after practice to distinguish along with them a third tone, called the *difference tone*. Difference tones arise from the interaction of two sound waves. Suppose we strike two tuning forks, one of 256, the other of 255 vibrations. Then once every second the two waves will reinforce each other and make a louder sound; and once every second the two forces will be working against each other — the one pushing the particles forward, the other pushing them backward — so that the result will be a softer tone. This loud-and-soft effect constitutes a *beat*, and the number of beats is equal to the difference between the vibration rates of the two tones. When a tuning fork of 256 and one of 266 vibrations are sounded together there will be ten beats a second, and so on. As the difference between the two tones is gradually increased the beats increase in number and at length become so rapid as to be indistinguishable; they then pass over into a deep tone, which is the difference tone. The rate of a difference tone is always equal to the difference of rate between the two primary tones.

When two tones differing by more than 16 vibrations are sounded together we may hear three tones — two primary and one difference tone; when three tones are sounded we

[1] When two different color stimuli are applied to the same retinal spot at the same time (or nearly so), as in color-mixing, the summation occurs in the process of stimulation, not centrally.

may hear six — the three primary and the difference tone of each pair; and so on. The primary tones and difference tones fuse together into one complex impression. These complex sensations are called *compound clangs*.

A *noise* may be regarded as the limiting case of a compound clang. It is composed of a very great number of tonal constituents. If we take into account all the observably different simple and compound clangs, the total number of auditory qualities is many times greater than 11,000.

Intensity. — Differences in the amplitude (force) of sound waves produce *intensity* differences in the auditory sensation. To determine the least perceptible difference in auditory intensity a steel ball is dropped from a standard height and then from a slightly greater height. The variable height is altered gradually until the subject just notes a difference in intensity between the two sounds.

The faintest audible sound is reported to be that produced by dropping a cork weighing 1 mg. from a height of 1 mm., the ear being 91 mm. distant. The upper limit of intensity has not been determined. Loud sounds tend to become more and more painful, and in the end produce actual injury to the ear-drum.

3. Smell (Olfaction)

Structure of the Olfactory Receptor. — The receptor for smell is far simpler than either the ear or the eye. In fact none of the other sense receptors begin to compare in complexity with the organs for sight and hearing, with the single exception of the static receptor.

The olfactory sense is closely associated with the function of breathing. Its receptor consists of a number of spindle-shaped cells situated in the mucous lining of the nostrils. [Figs. 48, 49.] Each olfactory cell is connected with a fiber of the olfactory nerve. In man the olfactory spindles are located in a small region far back within the nasal cavity at the

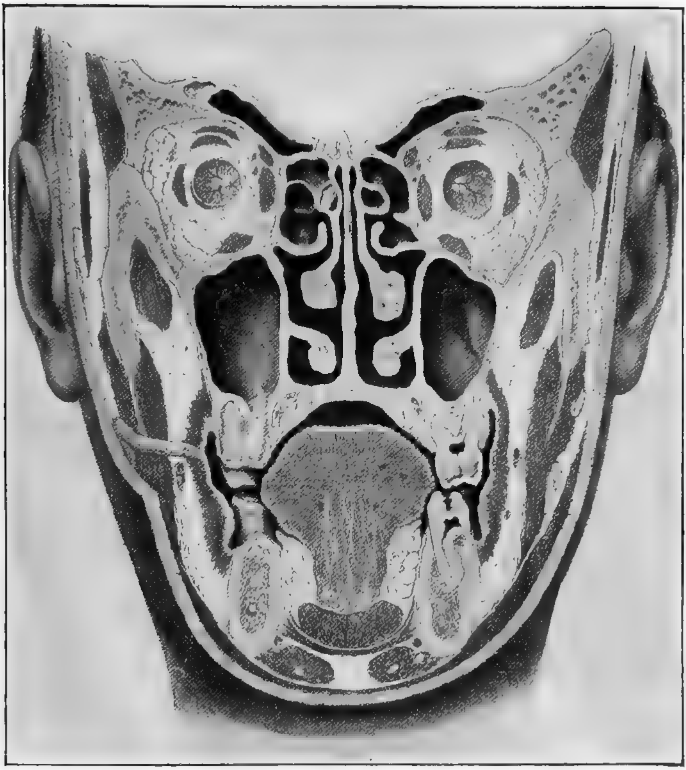


FIG. 48. — NASAL CAVITY AND OLFACTORY REGION

Vertical section, viewed from front, passing through back of eyeballs. The olfactory region lies mainly at the upper end of the long, narrow passages at each side of the central dividing membrane (septum). [From Wenzel.]

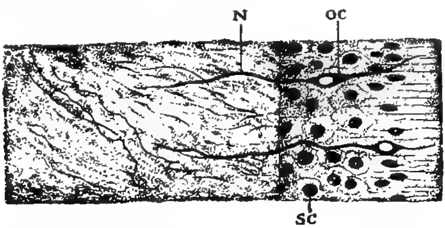


FIG. 49. — OLFACTORY CELLS

Section of olfactory mucous membrane, showing olfactory cells (OC) and nerve fibers (N) which connect with them. SC = supporting cell. [Based on Piersol.]

top of the passage way. In many animals, such as the dog and moose, this sense and its receptor are much more highly developed than in man.

Olfactory Stimuli and Physiology of Smell. — The stimulus for smell consists of very minute particles which emanate from various objects (especially organisms) and permeate the surrounding air. They sometimes travel great distances. These emanations are drawn into the nostrils in breathing. As they pass through, some strike the olfactory cells and stimulate them. The process of stimulation is apparently a chemical action. The fibers of the first cranial nerve terminate at the spindles and carry the impulses to the olfactory center in the brain. The stimuli include many varieties, which produce different modes of impulse in the olfactory nerve.

Sense Characters: Qualities. — Despite the apparent simplicity of the receptor for smell we distinguish many different qualities in the olfactory sensations. The olfactory qualities are called *odors*. So far as can be determined the odors do not form a continuous series like the color hues and auditory tones. Possibly further observation and experiment will bring them into serial order. The catalogue of qualities is by no means completed. New varieties of odor are often discovered when

TABLE X. — CLASSES OF ODORS

Class	*Examples*
1. Ethereal	All fruit odors
2. Aromatic	Camphor and spicy smells; anise, lavender, etc.
3. Fragrant	Flower odors; vanilla; gum benzoin, etc.
4. Ambrosiac	Amber; musk
5. Alliaceous	Garlic, asafœtida; bromine, chlorine, etc.
6. Empyreumatic	Toast, tobacco smoke; naphtha, etc.
7. Hircine	Cheese, sweat, etc.
8. Virulent	Opium, cimicine, etc.
9. Nauseous	Decaying animal matter, fæces, etc.

[From Titchener, *Exp. Psychol.*, Vol. I, Part II, p. 112; after Zwaardemaker.]

we scent new fruits or flowers or new chemical compounds. At present all we can do is to group the olfactory qualities into a number of classes. The members of a class resemble one another in a general way and differ noticeably from those of other classes. Nine distinct classes are observed, each of which includes a large number of different odors. [Table X.] The so-called pungent odor is not an olfactory quality but a tactile sensation akin to tickling.

Intensity. — Intensity differences in smell depend not so much upon the force of the individual stimuli as upon the number of particles which affect the receptor simultaneously; this varies with the density of the emanation. The least perceptible difference of intensity may be determined by means of a series of bottles containing the odorous substance in different degrees of dilution. The more concentrated the solution, the more particles will emanate from it, and hence the greater the intensity.

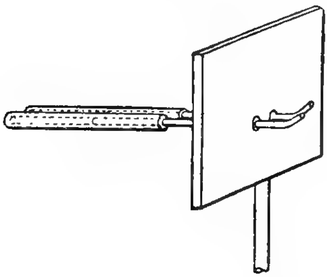


FIG. 50. — OLFACTOMETER

The two bent tubes at right are inserted in the nostrils. Solid frame conceals other end of tubes from the observer. Hollow tubes lined with odorous substance are shown at left, drawn partly over the olfactometer tubes. [From Titchener, after Stoelting.]

Intensity tests are also made with the olfactometer. [Fig. 50.] This apparatus consists of two parallel tubes, curved at one end for insertion in the nostrils. Tubes lined with substances containing odorous particles are drawn over the straight end of the olfactometer; the intensity of the odor varies with the amount of exposed surface of odor-bearing substance.

Either of these apparatus may be used to determine the threshold of intensity. The least perceptible intensity varies widely according to the substance used; for mercaptan it is

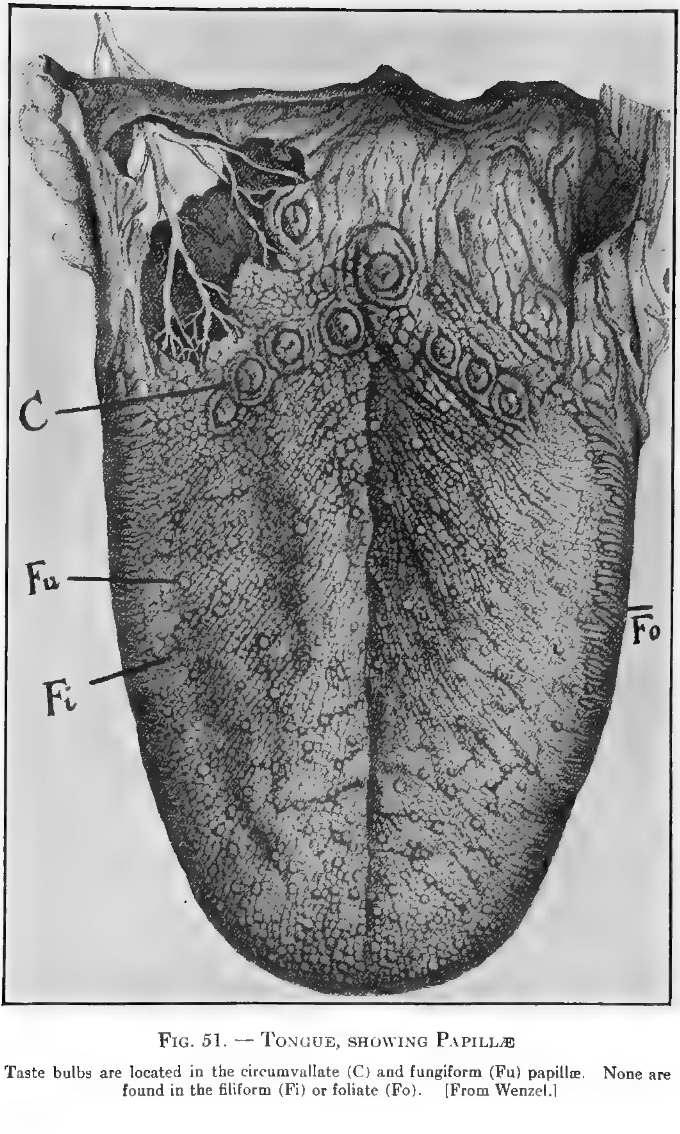


FIG. 51. — TONGUE, SHOWING PAPILLÆ

Taste bulbs are located in the circumvallate (C) and fungiform (Fu) papillæ. None are found in the filiform (Fi) or foliate (Fo). [From Wenzel.]

about 0.000,000,043 mg. in a liter of air; this is one of the lowest thresholds.

In man, smell is decidedly inferior in importance to sight and hearing, and even to touch and the muscle sense. It serves practically to warn us of danger from noxious substances; it has also developed a certain esthetic value comparable to that of music. On the whole this sense appears to be losing in importance with the progress of the human race; its data play a minor rôle in the mental life of civilized man.

4. Taste (Gustation)

Gustatory Receptor and Stimuli. — The sense of taste is closely related to smell. Their evolutionary history goes back to a common origin, the chemical or food sense. But whereas objects which arouse the smell sensation are often at a considerable distance from the body, the substances which we taste act only through contact with our organism.

The receptors for taste are certain cells shaped like bulbs or flasks which are inserted in the mucous lining of the tongue and palate. [Figs. 51, 52.] These bulbs have a small opening at the 'neck' end which receives the stimulus. The stimuli are always in liquid form; solid substances are tasted only when dissolved by action of the saliva. Fibers from three distinct cranial nerves connect with the taste bulbs at various parts of the tongue and convey the impulses furnished by the stimuli to a taste center in the brain.

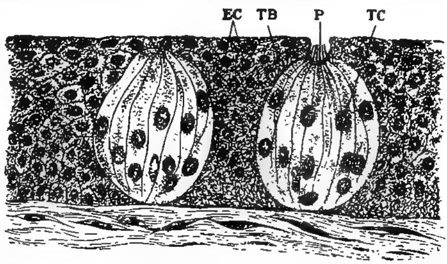


Fig. 52. — Taste Bulbs and Taste Cells

Section of lining of papillæ, showing taste bulbs (TB), with pore (P) at neck and taste cells (TC) forming part of bulb; EC = epithelial cells. [Based on Piersol.]

Characters of Gustatory Sensation. — Taste sensations are often mistaken for odors, and this confusion has led to the prevalent belief that taste affords a great variety of different qualities. Much of the food taken into the mouth consists of odorous substances. The emanations pass up into the nostrils and affect the olfactory receptor. From the location of the stimulating body the sensation is ascribed to taste. An onion and a potato differ decidedly in smell but not in taste. Unless a crucial test is made by holding the nose while eating, we invariably attribute part of their quality differences to taste. The combination of smell and taste makes up the *flavor* of food.

Careful experimenters discriminate only four qualities in taste:

Sweet
Sour (or acid)
Saline
Bitter

Some observers notice two other qualities, metallic and alkaline. These are probably due to a combination of taste qualities. Other so-called qualities of taste are fusions of taste sensations with sensations of warmth or cold and contact. The four qualities do not form a series; they bear no special relation to one another except that sweetness contrasts to a certain extent with the other three.

The least perceptible difference in intensity of tastes may be tested very much as in smell. Bottles are prepared with solutions of some tastable substance in varying degrees of concentration. These solutions are applied successively to the tongue by means of a brush. Exact determination of the threshold is difficult, owing to the persistence of gustatory stimuli; it is not easy to remove the tasteful substance from the tongue quickly enough to admit close comparison with the next stimulus. The least perceptible intensity of taste differs widely for the four qualities. [Table XI.]

TABLE XI. — THRESHOLD OF INTENSITY FOR TASTE

Quality	*Substance*	*Dilution in water*
Bitter	Quinine	1: 390,000
Saline	Salt	1: 2,240
Sour	Sulphuric acid	1: 2,080
Sweet	Sugar	1: 199

[From Sanford, *Exp. Psychol.*, p. 48, after Bailey and Nichols.]

5–7. CUTANEOUS SENSES: TOUCH, WARMTH, COLD

Receptors for Cutaneous Sensibility. — The outer surface of the body is susceptible to several kinds of stimulation. The resulting sensations are grouped together in popular language under the name of 'touch.' Careful investigation, both by self-observation and study of the cutaneous receptors, has led to the distinction between the sense of *touch* proper and senses of *warmth*, *cold*, and *pain*.[1] The sensations of warmth and cold constitute distinct qualities, and their receptors appear to differ from each other and from the touch receptors.

A difference in quality is observed in touch between the sensations of *contact* and *pressure*. Some points on the skin are susceptible to warmth and not to cold; for other points the opposite is true. By

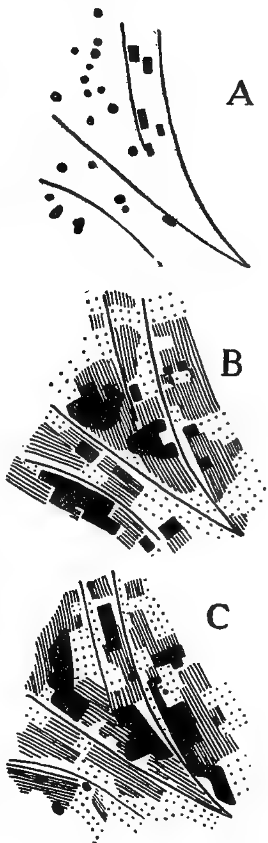


FIG. 53. — PRESSURE AND TEMPERATURE SPOTS

Map of palm of left hand, showing relative distribution of sensitivity to pressure (A), warmth (B), and cold (C). Same area represented in all, three cases. In A the regions marked black are relatively *insensitive* to pressure. In B and C the areas *most sensitive* (to warmth and cold respectively) are marked in black, less sensitive in lighter shading, etc. [From Schaefer, after Goldscheider.]

[1] For discussion of pain see p. 207.

minutely exploring a section of the skin first with a warm needle and later with a cold needle, a map of the warmth spots and cold spots may be made and it is found that their locations in the given area are quite different. Pressure spots are mapped out in the same way and their topography differs from the other two. [Fig. 53.] These spots may remain practically unchanged for months.

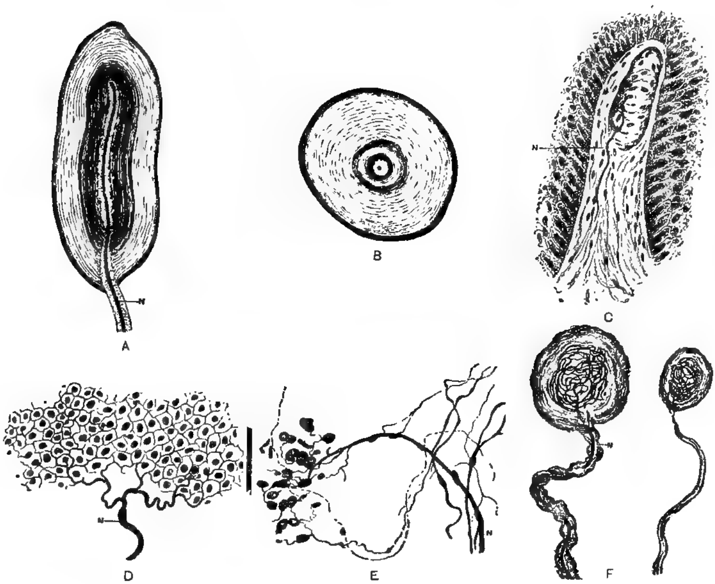


FIG. 54. — TYPES OF CUTANEOUS RECEPTORS

A. Vater-Pacini corpuscle; longitudinal section from skin of child's finger.
B. Transverse section of same.
C. Meissner corpuscle.
D. Free nerve endings in epidermis of rabbit.
E. Merkel cells in interpapillary epithelium.
F. Krause end-bulbs from human conjunctiva.
N = nerve fibers. [Based on several drawings.]

Examination of the structure of the skin reveals several different kinds of corpuscles embedded within it and apparently connected with nerve endings. The most noticeable of these

in man are the corpuscles of Vater-Pacini, Meissner, Krause, and Merkel. [Fig. 54.] Some of these types lie near the surface; others lie deeper in the skin. It is now generally assumed that these several types are receptors for different cutaneous senses. Observers are not in agreement as to which serves for which.

The receptors for warmth apparently lie deeper than those for cold, since their response requires a longer time. There appear to be two different receptors for touch — one lying deeper than the other. In certain pathological conditions one kind of cutaneous sensation may be lost while others remain. These anatomical and pathological observations have led recently to a distinction between *epicritic* (surface) and *protopathic* (deeper-seated) senses. Cold is epicritic and warmth protopathic; the contact sensation is epicritic and pressure protopathic. The distinction as applied to warmth and cold is confirmed by self-observation, but it is not clear whether contact and pressure are distinct senses or merely two qualities of touch.

The receptors for touch, warmth, and cold are distributed over the entire outer surface of the body. There are tactile corpuscles at the roots of the wide-spread body-hair; they are found also in the eyeball, tongue, and other special organs. Some of the inner organs are sensitive to contact and pressure but not to temperature stimuli.

Qualities and Intensity of Cutaneous Sensations. — Each of the two temperature senses has one characteristic quality — *warmth* and *cold*, respectively. When the warmth and cold receptors are stimulated together the result is a sensation of complex quality known as the *heat* sensation.

The sense of touch (assuming it to be one sense) has only two elementary qualities, *contact* and *pressure;* but under special conditions of stimulation it gives rise to certain peculiar quality effects. We distinguish in a qualitative way between sensations of *roughness*, *smoothness*, *moving contact*,

moisture, and *stickiness*. The sensations of *tingling* and *itching* appear to be touch qualities; they are generated by stimuli within the body and are sometimes attributed to the organic senses. The peculiar sensation known as *tickle* differs strikingly from most sensations in that a very faint stimulus yields a very intense sensation. The tickle sensation is probably due to a definite touch stimulus applied to a very small area. The other special touch qualities are due to spatial and temporal variations of the stimulus.

Differences of intensity may be examined in touch, warmth, and cold by methods analogous to those used in the higher senses. The least perceptible intensity in touch is stated to be the contact of a cork weight of 2 mg. on the tip of the finger. For the temperature senses the least perceptible sensation is produced by a stimulus about $\frac{1}{8}°$ warmer or colder than the normal temperature.

While the cutaneous sensations present no great variety of quality, they furnish considerable information about the near-by environment and indicate the mutual relations of different parts of the body. The data derived from touch are highly important in perception, especially in the determination of space relations (ch. xii). Warmth and cold are less significant factors in mental life. Their data usually combine with tactile sensations to form complex experiences; they rarely yield separate perceptions.

8. Organic Senses (Cœnesthesia, Visceral Senses)

Classes of Systemic Sensations. — The senses so far considered are affected by external stimuli. We come now to a group of senses which furnish data concerning the vital life of the organism itself. The whole group are called *systemic senses*. They include (1) senses associated with specific physiological processes; (2) general sensibility; and (3) the pain sense. The first two may be grouped together under the gen-

eral name of *organic senses;* they are also called visceral senses and cœnesthesia.[1]

Owing to the deep-seated location of their receptors the organic senses are extremely difficult to investigate, and our knowledge of them is still somewhat confused. Not only is it difficult to determine exactly the number of different sense-qualities, but it is uncertain how many of them constitute separate senses with distinct receptor organs.

Qualities of Organic Sensations. — The most distinctive organic sensations are those associated with the digestive, vascular, and sexual functions. Among the *digestive sensations* casual observation distinguishes between *hunger* and *thirst.* Under careful examination the sensation of hunger proves to be a complex phenomenon. It includes (1) hunger *pangs,* due to muscular contraction in the stomach; (2) appetite or *craving* for food, which sometimes occurs even when the stomach is filled; (3) general discomfort due to *starvation* and depletion of the tissues. In addition to these we find (4) a separate sensation quality, which accompanies the *satisfaction* of hunger. *Thirst* is probably due to a drying of the mucous membrane in the pharynx. It is doubtful whether the sensation of satisfied thirst is distinct from general sensibility. Another digestive sensation is *nausea,* which possesses a very pronounced quality. There is also a specific sensation in the digestive tracts due to *distension* of the stomach and other cavities. Less definite sensations accompany the later digestive processes in the intestines, bladder, etc. There are also specific sensations connected with urination and defecation. Associated with these is a sensation localized in the abdominal region, which is stimulated under emotional conditions of fright, anger, affection, etc. Although the above-mentioned sensation qualities are all associated with the di-

[1] The term *organic sense* is often used more broadly, to include muscle sensations; these belong to a different class. Sensations from receptors in the thorax as well as in the visceral organs come under the head of organic senses.

gestive processes they are due to distinct stimuli and in many cases probably involve distinct receptors.

The *circulatory processes* are accompanied at times by distinctive sensations such as flushing, heart quavers, and the like. The *respiratory processes* under certain conditions also give rise to distinct sensations. Sensations from both circulation and respiration appear in states of trepidation, anxiety, and panic. In general, however, these autonomic processes proceed without any distinctive sensations apart from a condition of general sensibility or *feeling*.

The *sexual functions* give rise to distinctive sense qualities known as sexual craving, orgasmic sensation, and sexual satisfaction. They probably contribute also to the tone of general sensibility.

General sensibility or *feeling* is the obscure sensation which pervades the body at any given moment. It includes two opposite qualities, *pleasantness* and *unpleasantness*. It is probable that general sensibility has no specific receptor of its own, but is due to certain common characteristics of the stimuli which affect the various organic receptors. The metabolic changes which occur within the body are of two opposite sorts: anabolism or building up of chemical compounds, and katabolism or breaking down of existing compounds. Anabolism and katabolism probably stimulate all the receptor organs. They modify the impulses due to the specific stimuli for each receptor, and give rise to the two phases of sensation known as pleasantness and unpleasantness respectively. In the external senses the specific characters of the stimuli are so pronounced that the general sensibility factor is usually of minor importance. In the organic senses (and pain) on the other hand, the specific mode of the stimulus is but little differentiated, while the metabolic stimuli are very pronounced. Hence the distinctive feature of organic sensations in most cases is the *feeling tone* or general sensibility. An organic sensation is determined primarily by the meta-

bolic stimulus, and only secondarily by a specific type of stimulus. Most of our digestive and other organic sensations are observed chiefly as feelings of pleasantness or feelings of unpleasantness; their specific sense qualities are subordinate.

In addition to the general sensibility connected with specific organs, we experience a *total feeling of sensibility* in the body as a whole. This sensation is determined by the balance between the various anabolic and katabolic processes which are taking place at the time; but it takes on a quality tinge of its own, due to the summation of various obscure sense-qualities. The total general sensibility is characterized, according to varying conditions, as *well-being*, *repletion*, *drowsiness*, *discomfort*, *fatigue*, *vigor*, *weakness*, and the like.

9. Pain Sense

Pain Stimuli and Qualities of Sensation. — The pain sense is distinct from the organic senses and general sensibility, but like them it furnishes data concerning the vital life of the organism. No specific receptor for pain has been discovered. The stimulus apparently affects directly the free endings of a group of sensory neurons which terminate in various parts of the body, especially near the periphery. [Cf. Fig. 54 D.]

Pain sensations occur in connection with sensations of other types. When a very intense stimulus of any sort is applied to the skin the specific receptor for warmth, cold, or pressure takes up only part of the energy. The remainder is diffused through the tissues and stimulates the free endings of the pain nerves. These nerves lead to a separate center in the brain. The pain sensation begins somewhat later than the specific sensation which accompanies it.

Pain has a very prominent metabolic component, always katabolic. The sensation is characteristically unpleasant. Its specific qualities are difficult to discriminate from those of the accompanying sensations. Pain in the eyeball appears

to have a different quality from the pain of a bruise or soreness of the skin. More probably the difference is not in the pain sensation itself, but is due to the blending of muscle or touch sensations with pain. We discriminate sharp, incisive pains from vague, diffused pains; but this distinction may be due to the number of nerve endings affected or to intensity of stimulation. The distinction between throbbing pains and prolonged pains of even intensity depends upon temporal variations of the stimuli. There is a marked difference, as Titchener points out, between the bright pains which originate near the surface of the body, and the dull pains connected with the internal organs, but whether this constitutes a qualitative distinction is by no means certain.

Pains are distinguished and named with reference to the accompanying sensations or according to their extent and duration. We distinguish between scratches, pricks, stings, and sores (touch); burns (temperature); stomach pains, nausea, intestinal pains (organic); bruises and muscular soreness (kinesthetic). Eye pains and earaches are organic; they are not connected with the special senses mediated by these receptors.[1] Headache is due to local stimuli in that region. Shooting neuralgic pains are apparently due to internal stimuli which affect the nerves at some point of their course. Toothache is due to stimulation of specific nerves which terminate in the teeth.

However disagreeable the pain sensations may be in themselves, they play a prominent rôle in the life history of the individual, since they warn him of danger from without and within, and enable him to remedy harmful conditions. The elaborate mechanism for pain reception which has evolved among the higher organisms, and the prevalence of pain phenomena in these species, indicate the extreme importance of this sense in mental life.

[1] Certain eye pains are tactile; others are due to strain of the eye muscles (kinesthetic); occasionally they arise from intense visual stimuli.

10. Kinesthetic Senses (Muscle Sense)

Classes of Motor Sensations. — We have examined two groups of senses: those which give information concerning external objects, and those which report conditions within our own body. We now come to a third group — the senses which give information regarding our bodily movements and which indicate the position of our body in space and the mutual relation of its members. For want of a better term we may call this group the *motor senses,* although their data indicate position as well as movement. The motor senses include (1) the *kinesthetic sense* or senses, usually known as the *muscle sense,* and (2) the *static* or *equilibrium sense.*

Kinesthetic Stimuli and Sensations. — Kinesthetic sensations arise through stimulation of a group of sensory nerves which terminate in the muscles, tendons, and joints. The specific receptors for these senses have not yet been identified, but the sensations themselves are readily observed. In certain pathological conditions involving anesthesia of touch and temperature, the sensations attending movement of the limbs persist; conversely, in other diseased conditions, movements of the limbs yield no sensation while touch sensations persist. It has not been definitely determined whether the muscle, tendon, and joint sensations constitute three separate senses, or are merely variations of a single kinesthetic sense. The term *muscle sense* is commonly applied to the whole group.

Kinesthetic sensations are stimulated by movements of any of the striate (voluntary) muscles. [See Fig. 20, p. 53.] The sensations may be observed by moving the finger, elbow, knee, eyelid, eyeball, tongue, neck, foot, etc. The impression is quite different in quality from contact or pressure.

The position of our members in space is also indicated by kinesthetic sensations. In most cases the muscles occur in pairs, one of which is antagonistic to the other. When a member is held rigidly in any position, each of the antago-

nists is subject to a certain amount of contraction; the two resulting sensations together indicate the relative degree of muscular contraction and hence the position of the member. This may be observed if we close the eyes and hold the arm rigid in some position where it does not touch the body, or if we twist the neck to right or left and keep it fixed. When we flex the fingers or knee we obtain a distinct sensation of movement.

The muscle-sense data are usually reinforced by tactile sensations, such as the scraping of the clothes against the skin, and by indications from other external senses. When the eyes are turned from side to side, the motion of the whole field of objects across the retina results in a general change of visual sensations; in walking we have a visual picture of the moving scene. These auxiliary motor indications from the external senses (touch, sight, hearing, etc.) are not properly speaking kinesthetic sensations at all, but they assist materially in our perception of position and movement; they may be termed *secondary motor sensations.*

Kinesthetic Qualities and Intensity. — Careful observers report that the sensation obtained when the arm is moved differs in quality according as the movement is actively performed, or is made by someone else taking hold of the arm and bending it. Part of this difference, however, is due to contact and pressure sensations which accompany the forced movement.

The quality differences among muscle sensations, joint sensations, and tendon sensations are few in number. When we are actively pushing, or lifting a heavy object, we obtain a sensation called *effort;* when a member is resisting external pressure there is a sensation of *strain.* These sensations are assigned to the tendons. When the muscles have been active for a long time a sensation arises of muscular *fatigue;* this is possibly a form of general sensibility.

The intensity differences of the kinesthetic sensations are

very pronounced and finely discriminated. A very slight movement of the finger or arm is readily observed, and the movements of our limbs are regulated very precisely by means of these indications. This may be easily tested by observing how many different positions of the finger can be discriminated with the eyes closed. The least perceptible difference of position for the middle finger is found to be 1°.

The kinesthetic senses not only serve to inform us of our various postures and movements, but they also give information regarding the weight of external objects. If we lift a heavy object, the added resistance increases the intensity of the muscular contraction, and hence the intensity of the kinesthetic sensation is greater than when we merely raise the arm.

Insofar as they furnish indication of the weight of objects the kinesthetic sensations might be classed among the external senses. Their chief rôle, however, is the regulation of motor activity.

11. Static Sense

Static Receptor and Stimuli. — The receptor for the static sense is a complicated structure in the inner ear known as the *semicircular canals.* These canals are three in number and are placed at right angles to one another in three different planes. [Fig. 55.] They consist of osseous tubes filled with a liquid called *endolymph.* The semicircular canals connect with the vestibular portion of the inner ear at the utricle. [See Figs. 43, 45 A.] The latter (as well as the saccule) contain minute crystals called *otoliths.* The function of the utricle and saccule is not altogether clear. They may be sense organs which give data regarding position of the head in relation to gravity.

The stimuli for sensations of the static sense are alterations in pressure of the endolymph which result from changes in the position of the head. Since the semicircular canals lie in the

three planes of space, any angular change whatsoever in the position of the head involves rotary motion of at least one canal about its axis. When this rotation occurs the inertia of the liquid inside the canal causes greater pressure at one end and less pressure at the other. Similarly, if the whole head is moved linearly in any direction the pressure at both ends of one of the canals will be increased or diminished. The changes in pressure of the endolymph is believed to stimulate nerve endings of one branch of the eighth cranial nerve; the resulting nerve impulses are carried to the static center in the brain.

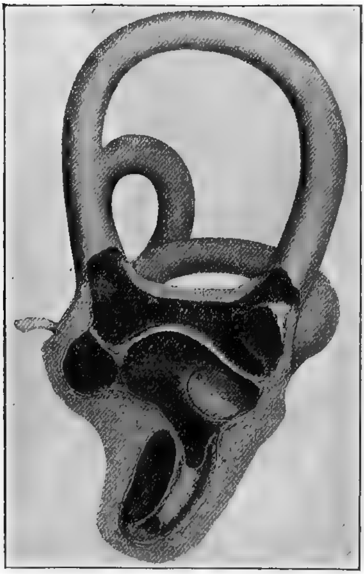


Fig. 55. — Semicircular Canals

[From Wenzel.]

Since the canals are situated in the inner ear and are supplied by a branch of the 'auditory' nerve, they were long supposed to have some function connected with hearing. It was found, however, that when the canals are excised in pigeons a very marked disturbance of motor coördination ensues. The bird is unable to regulate his flight or to maintain his balance. It is now well established that this organ represents a sense entirely distinct from hearing. Comparative morphology demonstrates that the sense of hearing arose much later in the animal scale than the static sense and is an off-shoot of the latter. In man, however, hearing has become so highly developed that it plays a far more important rôle in mental life.

The static sense gives sensations of *position* and sensations

of *motion*. In both cases the static sensation is so closely bound up with muscle sensations and other kinesthetic data that it is difficult to distinguish its own particular quality. The sensation of motion apparently differs in quality from the sensation of position. The latter, as noted above, may arise in the utricle and saccule. The sensations from the three semicircular canals may also differ in quality; more probably the differences observed are similar in nature to the local signs found in the sense of touch, which enable us to distinguish contact on the finger from contact on the arm, face, and elsewhere.

The static sensations of motion vary in intensity according to the intensity of stimulation, which varies with the velocity of the movement. The differences of intensity may be observed by lying flat upon a rotation table, with eyes closed, while the table is turned at various rates of speed. The least perceptible motion is a rate of about 2° per second, starting from a standstill.

The stimulus for static sensation is the *acceleration* of motion, not the velocity. If we are rotated on the table at a uniform rate, the sensation gradually dies away and we finally appear to be motionless.[1] When this state of apparent rest is reached, if the rate of rotation (hitherto uniform) be slowed up considerably, the subject obtains a sensation of motion *in the opposite direction*, though the table may still be rotating in the original direction.

The data of the static sense combine with those of the kinesthetic senses and with motor data from the external senses to give information of our bodily postures and movements. All these data are intimately associated with the formation of motor habits and with the adjustments of movements generally.

[1] The experience of rest is not perfect if the apparatus jars or creaks.

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PRACTICAL EXERCISES:

Listen for difference tones and overtones on the piano (or violin, etc.) and describe the experience.

Examine three different sorts of organic sensations, e.g., hunger, general bodily fatigue, toothache.

Observe the sensations of taste for various common foods while holding the nose, and compare with the usual sensations.

CHAPTER XI

THE COMPONENTS OF MENTAL STATES

Mental States and their Components.—In earlier chapters[1] the distinction has been drawn between mental life as observed in others and our own mental life as each one of us observes it in himself. The latter is called *subjective experience.* Consciousness is an abstract term which denotes the specific characteristic of these experiences — the fact that they form part of our *own* life. But there is nothing abstract about our conscious mental life. As we ' live along ' it consists of a series of definite concrete occurrences.

Each separate conscious experience is called a *mental state,* and the same term may be applied more broadly to any *part* of an experience which is distinct enough to be discriminated out and examined by itself. Our *present* mental state is the sum-total of our conscious experience at the present moment. Usually we can analyze our present experience into a number of rather distinct partial experiences. We may at one and the same time perceive a landscape, feel a thrill of pleasure, recall an incident in the past, and plan some future action. Each of these may be regarded as a 'mental state.'

Every one of our mental states in adult life is the result of a large number of nerve impulses, present and past, which combine together. Past impulses operate through their retained neural traces, and present simple impulses are summated at the centers. Certain other operations take place in the act of combination.[2] The result is a complex nerve impulse. It is these complex central impulses, observed by the individual himself, that constitute his mental states. The

[1] See chs. i and viii.

[2] See discussion of "Fundamental Operations of Nerve Substance," pp. 57-70, and of "Fundamental Operations of Experience," pp. 138–44.

simple impulses which enter into the complex impulses are called the *components* of mental states.

The components of mental states are not observed separately, but we may study them in their simplest compositions. We cannot, for example, isolate a pure 'red sensation'; but we can examine a perception of 'red surface' with the fewest possible complicating factors. To understand the nature of mental states we must first study the characteristics of their components.

At the close of chapter viii a distinction was drawn between two fundamental types of experience, *sensory* and *ideational.* Sensations are more fundamental data than ideas. Sensations are primary or *original* components of experience, while ideas are *derivative* components.[1]

1. Sensations

Characters of Sensation. — In chapters ix and x we examined the various classes of sensations separately. Under each sense we examined the mechanism by means of which the sensory neural process is stimulated and conducted to the centers, and noted the various qualities of sensations and their intensity differences. We shall now consider the characteristics common to all sorts of sensation, and the relations between the several senses.

Sensations, we found, arise as a result of stimuli acting upon certain specialized cells called receptors, or in a few cases as a result of stimuli acting directly upon the free endings of sensory nerves. The differences among sensory nerve impulses and the variety among sensations depend (*a*) upon differences in the stimuli; and (*b*) upon the constitution of the receptor organs. In other words, to explain the differentiation of the sensory components of mental states we must look *outside* the nervous system.

[1] Sensations and ideas may be grouped together under the name of *impressions.*

When a large number of sensations are observed and compared they are found to differ in two or more independent ways. Each independent manner of varying is called a *character* (or attribute) of sensation. The two most obvious characters of sensation are (1) *Quality*, and (2) *Intensity*. When the sensation is not limited to a single nerve impulse two additional characters may appear: (3) *Duration*, and (4) *Extensity*.

Rôle of the Stimulus. — The *quality* of a sensation depends ultimately upon the nature of the stimulus. Among sensations arising through the same kind of receptor, quality differences are due to the mode of stimulation. Thus differences among color sensations are caused by different rates of light vibration, and tone differences among auditory sensations are due to different rates of sound vibrations. Odor qualities are not caused by different rates of vibration, but are due to different ways in which various odorous particles act upon the olfactory spindles. The more striking differences between qualities from *different receptors* are also due to the modal factor. The visual sensation 'primal yellow' is due to a certain rate of light wave, and the auditory sensation c^1 to a certain rate of sound wave. These two stimuli differ in mode — the resulting sensations differ in quality.

Intensity of sensation is quantitatively related to the intensity of the stimulus. As the intensity of the stimulus increases, the intensity of the sensation also tends to increase, though not in direct proportion. The relation is represented by the logarithmic curve, as Weber and others discovered (ch. v). It may be expressed by the following simple formula: "As the stimulus increases in geometrical proportion, the sensation increases in arithmetical proportion." [1]

The two chief characters of sensation, quality and intensity, are thus directly dependent upon certain corresponding differ-

[1] The experimental results in connection with Weber's Law are treated in chapter xii.

ences in the stimuli which arouse these impressions. The *duration* of a sensation depends upon the duration of its stimulus, but the relation is not so close. On the one hand the beginning of the sensation lags somewhat behind the application of the stimulus. On the other hand the sensation may persist after the stimulus ceases to act. In general, however, the longer a stimulus acts upon a receptor, the longer will be the duration of the ensuing sensation. Hence, the temporal character of sensation is primarily a function of the stimulus.

Rôle of the Receptor. — The receptor is an essential factor in determining sensations. In the first place it is the receptor that determines whether or not any given force will act as a stimulus. There are many light waves of which we get no impression whatever, because the retinal elements are not capable of being stimulated by them. The infra-red and ultra-violet rays are just as much light waves as those within the limits of the visible spectrum; but their wave lengths are too great or too small, respectively, for the receptor organ. Thus the number of different qualities in each sense is limited by the capacity of the receptor. Moreover, there are forces in the environment for the reception of which no special organ has evolved. So far as we know, the magnetic force which acts upon the compass needle does not stimulate any receptor and gives rise to no sensation whatsoever.

Again, the quality of each sensation is determined in part by the constitution of the receptor. The series of *physical light waves* is a straight progression, but the series of *color qualities* has four critical points, at red, yellow, green, and blue, and the two ends of the series approach toward each other in similarity. In the series of auditory qualities, too, octave tones resemble each other more than tones of any lesser interval. These special relations among sensation qualities are due to the structure of the receptors and the nature of their activity.

The rôle of the receptor in determining the *intensity* of sen-

sation is not so important. In sight the intensity of the stimulus is modified by the receptor in several ways: (1) By contraction or relaxation of the iris muscle the amount of light admitted to the retina is regulated. (2) The layers of the retina in front of the rods and cones absorb some of the rays and temper the stimulus. Very intense visual stimuli are also tempered by winking the eye. But while these are all part of the reception process, they affect the stimulus before it reaches the real receptor.

The fact that the sensation intensity does not increase as rapidly as the stimulus intensity, indicates that it is affected either by the receptor or by the sensory neurons through which the impulse is transmitted. We do not know which. If Weber's Law held for all ranges of intensity the alteration might be accounted for by resistance and loss of nerve energy in transmission. But experiments show that the fraction of increase is greater for *both very small and very great intensities* than for medium intensities. This seems to indicate that the receptor is at least partly responsible for the loss in intensity.

The *duration* of a sensation depends to some extent upon the receptor. The persistence of sensation after stimulation has ceased is due to a residual process in the receiving organ, and the lagging of sensation behind the stimulus is due in part to inertia of the receptor process. Negative after-sensations are due to metabolic activity of the receptors.

One of the most important functions of the receptor is to furnish indications for the *extensity* (space) character of mental states. In those senses whose receptors are reduplicated and receive similar stimuli at various points (rods and cones, touch corpuscles, etc.) each individual receptor element is slightly different from the rest. Every individual rod or corpuscle is affected in a slightly different manner, even when the stimuli are identical. Hence the sensory impulse, in addition to its mode due to the stimulus, bears the mark of its

point of reception. These differences are called *local signs* (more properly, *locality signs*).

The grouping together of local signs by the summation of impulses furnishes a new kind of variation to our experience. This fourth character of mental states is the extensity attribute. It varies independently of quality, intensity, and duration. It is observed in mental states, not in their components. An object is perceived as large, extended, 'spaceful'; but the elementary sensations which compose it are not extended or large. The extensity character of mental states is based, however, upon the different local signs of the sensations which enter into their composition.[1]

Defective Receptors. — In certain individuals the normal condition of one or other of the receptors is altered through accident, disease, or specific inheritance. We noticed an instance of inherited abnormality in the phenomenon of *color blindness.* A corresponding defect, known as *tone deafness,* occurs frequently in hearing. The individual, while able to distinguish differences of pitch, is unable to recognize tone intervals, so that all tunes 'look alike' to him.

In such persons the range of one receptor or another is more limited than it is in the average man, either in respect to quality or intensity. As a result the individual experiences a lesser variety of sensations; fewer different components enter into his mental states. The extreme case is where one sort of receptor is entirely destroyed or incapacitated. Blindness and deafness are well-known instances of this. Loss of smell (anosmia) and taste (ageusia) are not uncommon, but are less noticeable because these senses play a less important rôle in mental life.

The effect of these abnormalities of the receptor upon the development of mental states is not so far-reaching as might be expected. Even the most extreme defects, such as blind-

[1] The manner in which space perception is derived from these sensory data will be treated in chapter xii.

ness and deafness, do not impair the normal course of mental life to the extent which we would suppose. If sensations of one class are lacking, data from other senses supply their place in large measure. The deaf learn to follow conversation by watching lip movements; the blind use touch and auditory data in finding their way about. There are two well-known instances in which sight and hearing have both been lacking, Laura Bridgman and Helen Keller. Both of these women by careful training attained a mental level above the average.

These facts emphasize the extreme importance of the central system in organizing mental life, and the relative unimportance of any one class of sensation. The receptors determine *what material* shall enter into our mental states, but the *manner of composition* is far more important than the nature of the components.

Classes of Sensations. — The most obvious classification of sensations is according to their receptors. All the data received through the eyes are grouped together as visual sensations, and so on. This was the system used in the two preceding chapters.

A satisfactory classification of the *senses* is more difficult to arrive at. It depends largely upon what we have in view. One scheme, often used in popular psychology, is based on the distinction between *special* and *common* senses. The special senses have highly differentiated receptors and furnish many varieties of sensation. The common senses have simple receptors, but these receptors are reduplicated many times and are scattered all over the body. Sight and hearing are the most specialized senses; touch and warmth are examples of common senses.

The senses are sometimes classed according to the process of stimulation. In sight, taste, and smell the stimulus produces *chemical* activity in the receptor; in touch, hearing, and the static sense the stimulation is apparently *mechanical.*

In comparative psychology the natural classification is based upon phylogenetic derivation. Hearing is an outgrowth of the static sense, smell is an evolution from taste, or from the food-sense which preceded taste.

A comparative study of the senses through the animal series shows the greatest diversity in their evolution. Some appear early in history and advance rapidly (sight); others appear early but remain undifferentiated throughout the animal scale (touch); some appear late, and of these some develop meagerly (warmth), while others become highly differentiated (hearing). In a word, the senses exhibit the most bewildering irregularity in growth and differentiation. If we attempt to systematize them according to some Hegelian system of *apriori* logic we find it a hopeless task.

This apparent absence of systematic development is readily understood if we realize that the origin of any receptor depends (1) upon the existence of a given force in the environment, and (2) upon chance differentiation of certain cells so that they become capable of receiving this force. The persistence of any receptor and its degree of specialization depend also (3) upon its usefulness in the mental life of the creature.

External, Systemic, and Motor Senses. — For our present purpose the most useful classification is according to the rôle which each sense plays in mental life. Some senses are especially concerned in furnishing data from the environment outside the body. These are called *external* senses. Others report the condition of the internal organs and tissues. These are known as the *systemic* senses. A third group report our bodily movements and the position of the body or of its various motile parts. These may be called the *motor* senses.

The receptors fall into three fairly distinct groups following these lines. (1) Certain kinds of receptors lie at or near the surface of the body and are excited by stimuli lying outside of the organism. They are called *exteroceptors.* (2) Other

receptors lie in proximity to the internal organs concerned in digestion, circulation, breathing, sex functions, etc. Their stimulation is brought about by the physiological activity of these organs. They are called *interoceptors.* (3) The third class of receptors lie in proximity to the motor organs and are stimulated when the muscles contract.[1] These receptors, although they lie within the body, bear a very different relation to mental life from the interoceptors. They give us an indication of our own movements and assist in our motor control. These receptors are termed *proprioceptors.*

The sensations furnished by these three groups of senses form the basis of very different types of mental states. The older psychologists recognized this in their distinction between cognitive, affective, and conative states or 'mental powers.' But in reality mental states are not so sharply demarcated as their components; the distinction applies to sensations rather than to full-fledged experiences.

Number of Different Sensations. — We cannot at present make any satisfactory estimate of the number of *different* sensory data which enter into the mental life of the average human individual. In sight there are believed to be about 30,000 distinguishable hues, shades, and tints; but if each rod and cone of the retina modifies its data by its own local sign, this would multiply the number by quite a large factor.[2] In hearing there are about 11,000 distinguishable tones; this number must be multiplied by a large factor to include the different intensities. There are no local signs in hearing, but if we treat the 'clang' as an elementary datum of experience the number must be multiplied still further to take in the many differences of timbre and the enormous variety of complex clangs which can be distinguished.

[1] The static sense belongs to this group, although its receptors are not connected with the motor organs.

[2] Not by the total number of rods and cones, however, since colors are not distinguished at the periphery.

There are many different qualities and intensities in smell, four qualities and many intensities in taste, with a few local differences. In the remaining senses the qualities are few in number but there are many distinguishable intensities. Local differences are numerous in touch and the kinesthetic senses, and somewhat less marked in the two temperature senses.

Taking into account the variations of quality, intensity, and locality in every sense, it is apparent that we are capable of receiving a vast number of different sensations as data of experience. The total number is more probably over a million than under that figure. Since the local signs of the receptors alter the mode of the nerve impulse, it may be stated as a general law that *all differences in sensory characters are due to variations in the mode or intensity of nerve impulses.*

Summary of Sensation. — Sensations are the original data which enter into the composition of mental states. The characters of sensation depend first of all upon the nature of the stimulus; but they are determined also to some extent by the constitution of the receptor.

The stimulus is more important than the receptor in determining the *quality* and *intensity* of sensation; but the differentiation of the receptor determines the number of discriminated qualities and intensities in any given sense. If a certain type of receptor is defective in any individual the range of the corresponding group of sensations is narrowed; if the receptor is destroyed or cut off from the sensory neurons the corresponding sensations are lacking altogether.

The stimulus determines the *duration* of a sensation, subject to a certain factor of deviation due to the operation of the receptor. The *extensity* character of mental states — the size and shape of the experience — is not due to the stimulus, but to the local signs of the receptors.[1]

[1] *Distance away* from the body is partly determined by the stimulus; see chapter xii.

The senses are divided into three classes: *external*, *systemic*, and *motor*, which perform different rôles in mental life. The classification is shown in Table XII.

TABLE XII. — CLASSIFICATION OF THE SENSES

Class of Senses and Receptors	*Senses*	*Sense Qualities*
1. External (exteroceptors) a. Distant (teleoceptors)	Sight	Colors (hues, shades, tints), grays
	Hearing	Tones, noises, timbre
	Smell	Odors of nine classes
b. Contiguous (proximoceptors)	Taste	Tastes
	Touch	Contact, pressure, etc.
	Warmth, Cold	Warmth, cold, heat
2. Systemic (interoceptors)	Organic	Digestive, vascular, sex, etc.
	Pain	Pains of various organs
3. Motor (proprioceptors)	Kinesthetic	Muscle, tendon, joint
	Static	Position, progression, rotation

2. IDEAS

The Ideation Process. — In this book the word *idea*[1] is used to denote any component of our mental states which is not the direct result of sensory stimulation. It should be borne in mind, then, that when we speak of *ideas* we do not mean full-fledged memories or any other image-states, but the elements which go into the composition of such mental states.[2]

An idea is an element of conscious experience whose quality does not correspond to the mode of any present stimulus or sensory impulse. Indirectly, every idea is the result of past sensory stimulation. For example, I hear the word 'McCosh,' and immediately afterward the image of my first teacher of psychology is "present in consciousness." The sound of the word calls up the image by suggestion; but there is no similarity between the sound which I hear and my

[1] The adjective is *ideational*, not *ideal*.

[2] This meaning of the term *idea* has considerable historic support, though it differs from popular usage.

visual image. Or again, I see a cardboard box and an iron box side by side; one ' looks ' light to me, the other ' looks ' heavy. The lightness and the heaviness do not directly correspond to any present stimulus — they are kinesthetic states, while the stimuli are visual.

In both these examples the mental states are made up in part of ideational elements. An idea is due to a nerve impulse in some part of the brain. But the quality of the idea does not correspond to the mode of the stimulus. The impulse has been modified and entirely made over. The resulting mode of the impulse (and quality of the impression) is determined by the retention effect of the neurons in some brain center. The set of the neurons has altered the mode of the nerve impulse as it passed into that region. Originally, this set was caused by sensory stimulation.

The rise of an idea may be pictured as follows: A sensory stimulus sends a nerve impulse to the brain. At some synapse in its central course, part of the impulse is distributed from the main path into an adjacent neuron. This overflow current, being less intense, loses its own mode and takes on the characteristic mode of the neuron into which it passes, this mode being determined by the trace left by past stimulation. The resulting central process is not a sensation, but an idea; it no longer retains the characteristic of its own origin. Not only may a sensory impulse be modified into an ideational impulse, but one ideational impulse may be modified into another in the same way. In subjective terms, a sensation is transformed into a very different idea, or one idea is transformed into another.

Ideation depends upon a complex, branching system of neurons in the brain; for if there is but one path of neural discharge there will be no overflow current and consequently no ideational experiences. Even in the species of animal just below man the mechanism for ideational processes is imperfectly developed. In the transition from lower primates

to man the development of the brain took a tremendous leap. In man there are many higher centers which receive impressions and retain traces. These centers are interconnected by association paths; a stimulus received at one center frequently passes to another, to still another, and so on indefinitely. This makes possible a long succession of ideational experiences before the nerve current passes over into motor paths. In a word, man has a mechanism which makes possible a highly intricate ideational life in addition to his sensory life. Among civilized races this type of experience has been especially developed and has come to be a most important factor in mental life.

Rôle of Ideas in Mental Life. — Ideational experiences bring about a more systematic and thorough adjustment of our reactions to our total environment. They act in a variety of ways.

(1) Ideas intervene between the sensory stimuli and our motor responses. At times a series of images or thoughts occur before the responsive activity begins. This delay serves as a check upon hasty and uncoördinated actions; it enables man to respond to the general situation, instead of to each particular stimulus.

(2) The ideational factors in our experience extend the environment to include our past as well as our present life. They build up a continuing personality in the individual, and add a temporal dimension to his mental life.

(3) Ideational experiences 'tone down' the effect of present stimuli. They lend perspective to one's whole life and career. A being with a well-developed store of ideational experiences is less centered upon the *here* and the *now* than one who lives and acts mainly upon immediate sensory situations.

(4) The growth of ideational life in man leads to a higher type of experience than imagery; the image develops into *symbolic thought* and *reasoning*, which form the basis of scientific knowledge and assist in a remarkable way to bring our

behavior and conduct into conformity with the objective world.

Distinction between Ideas and Sensations. — We noticed that sensations are the original data of experience. Ideas are derivative. Their quality is determined by the trace left in one or more of the cerebral neurons by some earlier impulse or by a number of similar impulses. In respect to quality elementary ideas are similar to elementary sensations, and the same relation holds of composite ideas and composite sensations unless the retention trace has been modified by dissimilar impulses occurring meanwhile. This qualitative correspondence is noted by observers who have prominent imagery of one sort or another. A good 'visualizer' can picture red, or he can picture the appearance of a friend's face. In either case the ideational experience is qualitatively like the original sensory experience. The same is true when (for example) we image the sound of the Meditation from *Thaïs* as played by a violin.

It follows, then, that we do not distinguish between ideas and sensations on the basis of quality. Ideas may be classified into the same divisions as sensations — visual, auditory, etc., except that in most individuals many of the sense classes do not have corresponding ideas, so far as can be directly observed.

Despite this correspondence, however, few of us have difficulty in distinguishing between sensory and ideational experiences, or between the sensory and ideational components in any given experience when we observe it carefully. The basis of this discrimination is two-fold: (1) the *intensity* of the data; and (2) in case of the external senses, the *controllability* of the data.

(1) The *intensity* of an idea bears no relation whatever to the intensity of the original stimulus; it depends entirely upon the strength of the present nerve impulse. In most cases the overflow current which arouses an ideational ex-

perience is comparatively weak. If we compare our memory or imagination of a sound with a sound sensation, we find in most cases that the memory and imagination images are far less intense than the sensation. Our 'picture' of a face is a less intensive experience than our perception of the same face. *Reduced intensity* is the mark by which we most frequently identify an idea as such and distinguish it from sensation.

(2) A second distinguishing mark between ideas and sensations is the *independence* of the latter. This criterion applies chiefly to the external senses. External stimuli lie outside of our organism; they form part of the objective world. Ideas depend upon our own past experiences. In consequence, sensations from the external senses are more independent of our system of activity than ideas; every now and then they provide something wholly new and unexpected. This independence is less noticeable in the systemic and motor senses. Kinesthetic sensations are generally produced as a result of our own motor impulses, and many organic sensations are due directly or indirectly to our motor activity. Both classes are capable of being stimulated by neural activity; they are said to be 'under control.' External stimuli are not under direct neural control; hence, when we arouse a visual or other external experience we class it as ideational.

Border-line Experiences. — These two criteria, intensity and independence, serve in most cases to distinguish sensory from ideational states. But they are not infallible tests. A sensory impulse may be so faint that the resulting impression is classed as an idea — or we may be uncertain as to its source. A similar confusion arises when an ideational nerve impulse is extraordinarily intense.

Dreams have all the vividness of sensations, owing to the absence of actual sensory impulses with which to compare them. Some of our most annoying hallucinations are due to

ideas which are so vivid that we class them as sensations. In conditions of high-strung tension we see a specter before us, or hear voices warning us, though the mental state is really ideational. At times we question whether a sound which we hear is 'real' — that is, whether it arose from external stimulation or was the product of central excitation. On dark nights we are not certain what we actually see and what we only imagine.

If the object appears to act independently of our control our error may be reinforced, or our uncertainty may be greater. In such cases the normal individual falls back upon a third criterion, the *uniformity and general consistency of experience.* We convince ourselves that the 'specter' is imagined, that the 'voice' is within us, because such experiences do not conform to the general scheme of things. Even in dreams the inconsistency of the experience occasionally convinces us that we are asleep.

The criteria by which we distinguish ideas from sensations are merely practical tests, based upon the general run of experience. In most cases there *is* a sharp dividing line, and the bulk of our experiences fall naturally into one class or the other. But neither the mental state nor its elements furnish a decisive indication of their original source. *Both sensations and ideas are central processes;* one sort may readily be mistaken for the other if its characteristics fall within the border-line territory.

Classes of Mental States. — Mental states are classed according to the kind of elements which compose them. In point of fact our actual experiences are rarely if ever made up wholly of elements of one sort. A perception usually has some ideational tinge, and our motor experiences are rarely devoid of some 'feeling' component. But in most of our mental states one or more types of element predominate; and for purposes of examination we classify the states which enter into mental life on the basis of their *dominating components.*

We distinguished between three kinds of sensation: external, systemic, and motor. Each of these gives rise to a corresponding type of idea. But only ideas of the external type develop sufficiently to act as dominant element in mental states. Ideational processes of the systemic and motor types lead almost invariably to stimulation of a corresponding sort and produce a sensation which supersedes

TABLE XIII. — CLASSES OF MENTAL STATES

PRIMARY

Mental State	*Dominating Component*
Perceptions	External Sensations
Imagery	External Ideas
Feelings	Systemic Sensations
Conations (Expressive States)	Motor Sensations

SECONDARY

Mental State	*Dominating Components*
Emotions	Systemic and Motor Sensations
Sentiments	Ideas and Systemic Sensations
Volitions	Ideas and Motor Sensations
Thought and Language (Social)	Ideas and Motor Sensations
Ideals and Rational Actions (Social)	Ideas; Systemic and Motor Sensations

the idea. When we think of a doleful occurrence the glandular processes are stimulated and the resulting experience is a sensation — a ‘feeling’ of sadness rather than an idea. In the same way if we think of making a movement we almost invariably send an incipient motor impulse along the proper channel, so that the motor picture is supplanted by an actual kinesthetic sensation.

A similar reinforcement occurs in the case of certain ideas derived from the external senses. When I think of a sound the muscles of my vocal chords are adjusted by a motor impulse and may bring about a whisper or incipient vocalization, so that the ideational processes are reinforced by a sensory stimulus. But in general the external senses are beyond motor control; the ideational experiences derived from them are not reinforced by corresponding sensations. A visual idea is not supplanted by a corresponding visual

sensation, and an olfactory idea does not bring about an odor sensation. We find accordingly that a class of mental states has developed whose chief components are 'external' ideational elements; but there are no well-developed mental states whose chief components are systemic or motor ideas.

Mental states may be divided into *primary* and *secondary*. Primary states include those in which one single sort of component predominates; secondary states are those in which two or more different types are prominent. There are four kinds of primary mental states: (1) *Perceptions*, in which the chief components are external sensations; (2) *Feelings*, based upon systemic sensations; (3) *Conations* or expressive states, based upon motor sensations; and (4) *Imagery*, based upon ideas derived from external sensations. Besides these, five well-developed secondary types are found in man.[1] A list of the primary and secondary mental states with their chief components is given in Table XIII.

Collateral Reading:

James, W., Principles of Psychology, Vol. II, chs. 17, 18.
Titchener, E. B., Textbook of Psychology, secs. 10–13, 112–114.
Royce, J., Outline of Psychology, chs. 4–6.
Stout, G. F., Manual of Psychology, Book IV, ch. i.
Judd, C. H., Psychology, General Introduction, (2d. ed.), chs. 4, 5.
Dunlap, K., System of Psychology, chs. 3, 6, 10.
Ogden, R. M., Introduction to General Psychology, chs. 7, 8.
Pillsbury, W. B., Fundamentals of Psychology, ch. 6.
Breese, B. B., Psychology, ch. 4.

Practical Exercises:

Make a list of your experiences during 15 minutes (e.g., just after the close of the last lecture yesterday). Classify according to their noticeable components.

Describe any experiences you can recall where you have mistaken an imagination for a perception or vice versa, or where you were unable to judge its real nature.

Analyze your total experience at some given instant (e.g., one minute before you first thought of starting this problem), and pick out its various sorts of components.

[1] The primary states are treated in chapters xii and xiii. For convenience imagery is taken up immediately after perception. The secondary states are discussed in chapters xiv and xv.

CHAPTER XII

PRIMARY MENTAL STATES

1. Perceptions

Nature of Perception. — Perceptions are mental states whose chief components are external sensations. The distinctive feature of perception is that many nerve impulses coming in separately from external receptors are combined so as to constitute a single complex experience. When we look at a painting we do not see a great number of color patches, each independent of the others; we perceive the picture as a whole. The sensations may differ in locality and coloring, but they form part of a unit experience. The specific neural basis of perception is the *summation* process. The separate sensory impulses from various neurons are collected into a single neuron at a higher level in the brain. The corresponding subjective process is *combination.*

In general our perceptual experiences correspond very closely to objects and events in the world outside our body. The space and time relations of objects and object-groups are fairly well reproduced in our central neural states. This general correspondence between external objects and the experiences which they arouse suggests a number of speculative questions about our knowledge of the outer world, which need not be discussed here.[1] But certain facts should be noted:

(1) The neural operation involved in perception takes place within the brain; it is a process of combining many nerve impulses which have reached the brain separately. This explains why our perceptions do not correspond in

[1] See Appendix, "Perception of the External World," p. 416.

every particular to the external objects which furnish the stimuli.

(2) Certain objects and forces in the environment are not perceived at all. We do not perceive ultra-violet colors, nor do we perceive the magnetic earth-current except by some indirect means, such as watching a magnetic needle; neither do we perceive objects visually, however near they may be, if they lie behind a stone wall. In such cases there are no sense data for the perception process to work upon.

(3) On the other hand, where sense data *are* present, the relations of objects and of their parts are perceived with greater exactness than the data warrant. When we look at a table we perceive the top as rectangular (as it actually is), even though the retinal picture has two acute and two obtuse angles; here the *sensation* group is diamond-shaped, yet we interpret the data correctly in perception, and perceive the object as a rectangle.

Perception includes several different kinds of combination. Besides mere grouping of data, it furnishes us discrimination, superficial space relations, object groups, temporal relations, subordination of parts, solidity, and perspective. These phases of perception appear to have arisen successively, in the above order, in the course of animal evolution; in the human child there are indications of a similar serial growth. For convenience we shall examine them in a slightly different order:

Simple perception
Surface perception
Depth perception and projection
Apperception (focused perception)
Object perception
Perception of events, time, and rhythm
Perception of differences (discrimination)

a. Simple Perception. — In most of the senses a number of stimuli occur together at the same time. When we open our eyes the whole visual field is usually stimulated at once.

In touch we are usually brought into contact not with a single point but with a region of stimulation. We usually hear not a single tone, but a complex sound or clang. In all these cases the stimuli are separate. Each rod and cone of the retina is provided with a separate neuron connecting with the visual center of sensation in the brain. Each corpuscle in the skin, each hair cell in the ear, is similarly connected with its own brain region by means of an individual nerve fiber. When the whole field of vision is stimulated the impulses from the individual rods and cones are carried separately to the brain. At each center (visual, tactile, auditory, etc.) these impulses are combined. As a result we 'see' a mass of colored points, we 'palp' a mass of touches at once. Our experience in any such case is not a single sensation, but a group of sensations which form a simple unit. The resulting mental state is called a *simple perception.*

In certain cases the impulses from two similar receptors unite to form a single impression. Thus in sight the impulses from the two centers of vision yield one impression, and so for each pair of 'corresponding points' in the retina. We see the whole field of binocular vision as a single field, not in duplicate. This is called *binocular fusion.*[1] In the same way a tone which stimulates both ears is heard as one tone, not two.

Most of our perceptual states go beyond the stage of simple perception. We perceive two patches of color as larger and smaller, as lying one above the other, etc. This leads to a higher stage of perception, in which the mental state involves space relations.

b. Surface Perception. — One of the most interesting problems in psychology is to explain how we perceive the size and shape of things and the relative position of different objects. The mental state which includes these relations is

[1] Where different colors are presented to the two eyes the central result is not fusion but *rivalry.* We perceive first one field, then the other, alternately.

called *surface perception.* It is not the perception of blank, unfilled space, but our ability to appreciate the distance and direction of things (or of their parts) from one another.

This type of perception is based upon the *local signs* of sensations, which are due to slight individual differences between each separate receptor.[1] Each rod or cone in the retina and each touch corpuscle in the skin differs from every other in its constitution. Owing to these 'local' differences the impulses stimulated by any receptor are slightly different in mode from those stimulated by the other receptors of the same sort, and this peculiarity of mode furnishes an indication of the source. This means only that we experience two simultaneous sensations as different — not that we perceive directly *how far* apart they are.

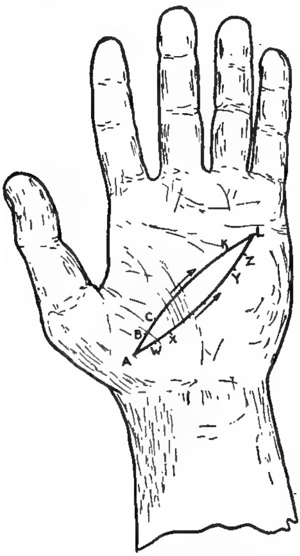

FIG. 56. — SPACE PERCEPTION IN TOUCH

Arrows indicate direction in which stimulus moves over the skin. (See text.)

Distance from point to point on the surface of the skin or retina may be called *superficial* distance as distinguished from *depth*, or distance away from the body. We are concerned only with superficial distance at present. Two separate factors serve to build up our appreciation of superficial distance.

(1) When objects move over the skin or across the retina, or when the skin or retina shifts over stationary objects, any given point on the object stimulates a number of receptors in the skin or retina *in regular order*. We rarely or never experience objects jumping hither

[1] See pp. 219, 220.

and thither in the field of touch or sight without stimulating the intermediate points.[1]

Usually objects moving over the skin affect the receptors in a certain succession. [Fig. 56.] As they pass over the skin from A to L the points B C . . . K are stimulated one after the other in this order. D is not stimulated before C, nor E before D. If the object does not move over the regular path A B C . . . K L, it moves over some other regular path, such as A W X Y Z L. In other words, there is a *regular succession* in the order of stimulation of points on the skin, and this is true whether the object moves across the station-

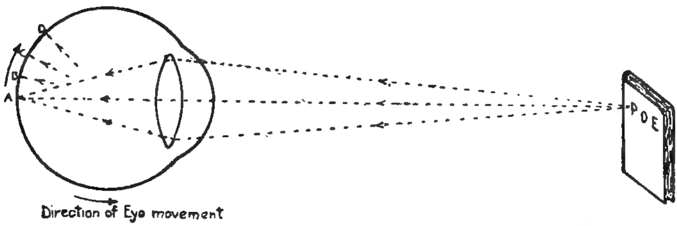

FIG. 57. — VISUAL SPACE PERCEPTION

Dotted lines indicate path of light waves toward the eye from a single point (P) in the object perceived, and their refraction in the lens, focusing at a point A on the retina. Fragments of dotted lines, ending at B, C, D, indicate the focusing of light waves from the same point P at successive points on the retina as the eye turns counter-clockwise. (See text.)

ary hand, or the hand moves over a stationary object. The same is true of the eye. In Fig. 57 the eye is supposed to move in the direction indicated by the lower arrow; the retinal picture of any object (e.g., the letter P on the book) shifts in the opposite direction, falling successively on A, B, C, D.

It follows that if a point on the skin or retina is situated far from the starting-point of stimulation it is not stimulated

[1] In the laboratory a jumping series may be devised by means of a set of lights in a dark room turned on and off in irregular order; or by a series of discontinuous touch stimuli.

immediately after the latter, but only after a large number of other points have been stimulated. Each regular touch series, A B C . . . K L and A W . . . Z L (and each regular visual series), occurs repeatedly in experience. These repetitions establish relations of 'immediate succession,' 'long after,' etc., between the various local signs — relations which correspond more or less exactly to the superficial distance of individual receptors on the skin or retina.

The retinal receptors are far more crowded together than the cutaneous receptors. The retinal surface is 'tremendously small' compared with the surface of the body; yet there are more rods and cones in the eye than touch corpuscles in the entire skin. This and our more frequent use of the eye has built up a finer system of space discrimination in sight than in touch. According to E. H. Weber [1] space discrimination at the center of the retina is 625 times as fine as on the tongue, which is one of the best developed tactile regions.

(2) The other factor in perception of superficial distance is the *kinesthetic sensations* which accompany eye movements and movements of the various bodily members. When we move the eye about (as indicated by lower arrow in Fig. 57) the movement is accompanied by a sensation of effort, due to stimulation of certain eye muscles. If the eye moves quickly through a large angle, A D, the muscle sensation will be different from that which occurs when we move slowly over a shorter distance, A B, even though the two movements occupy the same time. The effort in the first case will be more intense. The same is true of arm or hand movements. These muscle sensations accompanying the external sensations enable us to distinguish superficial *distance* from mere *duration* of movement. An object is perceived as distant from another not merely because a large number of

[1] *Tactsinn und Gemeingefühl* (ed. by E. Hering), pp. 74, 86. From Wagner's *Handwörterbuch d. Physiol.*, III, Abt. 2, pp. 531, 539.

other sensations intervene, but because the passage from one sensation to the other requires a considerable degree of muscular contraction.[1]

Kinesthetic sensations enable us also to distinguish *direction*. In Fig. 56 the distance A X is the same as A C. So far as the amount of movement and effort is concerned the two experiences are identical. But to move the hand from A to X involves a *different muscle* (or muscle combination) than the movement A to C; and this means different kinesthetic sensations. Each direction of movement involves different muscle sensations from every other. The perception of direction is due to these kinesthetic sensations. This applies not merely to hand movement and directions on the palm, but to muscular movement in any part of the body. In the case of eye movements the kinesthetic factor is more obvious; movements up, down, right, and left are due to entirely different muscles, each with its own local sign. These kinesthetic data indicate to us the direction of the eye movement and the direction of the various points on the retina from one another.

Central Mechanism. — The individual nerve fibers from various points on the skin gather together in the Rolandic region of the brain. It has been found that the fibers from the toes and feet terminate in the upper part of this region, the fibers from the face and head in the lower part, and those from the trunk, hands, etc., in between.[2] It is not known whether the central terminals of the separate fibers are spread out in a way corresponding to the space relations of their respective receptors. An exact spatial reproduction seems highly improbable.

The Rolandic region contains only the primary (sensation)

[1] Where kinesthetic data are lacking, the relative location of objects may be wrongly perceived. An advertising sign, "Gas Bills Cut in Two," seen at a glance, was read "Gil Blas Cut in Two."

[2] See Fig. 17, p. 48.

centers. The sensory fibers terminating there are connected by common association fibers which lead to higher (perception) centers. The impulses which pass over these association tracts are summation impulses, in which the components are grouped in certain definite orders, so that the higher centers in the brain receive impressions of the 'order' relation, as well as of specific touch qualities, warmth, etc. The same is true of the eye. Impulses from various retinal points are conducted separately to the primary optic center and from there a group impulse is conveyed through association tracts to the higher visual center.

When impulses summate together the resulting impulse undergoes *modification* and the corresponding mental state undergoes *transformation*.[1] In spatial summation of impulses the modifications and transformations all belong to one general type. If we examine a number of experiences which differ only in being caused by spatially different stimuli, we find that these differences introduce a new character or attribute — the spatial — which is not found in the component sensations. This may be analyzed into two factors, *superficial distance* (length and area) and *direction*. Distance and direction are independent variables in the space character of surface perception in the same way that color and brightness are independent variables in the quality character of visual sensation.

There is one important difference between the space character and the quality character: the spatial differences of perception are due primarily to differences among the individual receptors, while the quality differences of sensations are due primarily to differences among the stimuli which affect the receptors.

To review this discussion. Perception of two-dimensional space relations is based upon many experiences of the same general sort. (1) It is due to the regular order in which

[1] Cf. ch. iv, p. 69, and ch. viii, p. 143.

separate points on the skin and retina are successively stimulated. Each term in the ‘ order ’ of local signs gives some specific distance relation; their sum-total gives two-dimensional (or superficial) space. (2) The combination of kinesthetic sensations with specific sensations of sight and touch assists the spatial interpretation of local signs. It prevents errors in distance-perception due to slow and rapid movement. (3) Kinesthetic sensations also furnish ‘ direction signs ’ whereby the direction of one point from another is perceived. (4) The transformation process is an important factor in building up space perception, as we shall find it also in the production of other mental states.

c. Depth Perception and Projection: Visual. — A higher stage in the perceptual process is perception of the distance of external objects from our body. This type of perception, called *depth,* has developed in sight far beyond any other sense. The normal human individual, possessed of two eyes, on seeing an object perceives at once how far off it is situated. This perception is subject to error, and our errors in depth perception are far greater than in surface perception. The moon may ‘ look ’ only a few miles off, and a chasm may ‘ look ’ far deeper than it actually is. On the whole, however, the depth relations which have developed in sight correspond very closely to the depth relations in the external world. Perception of depth is not based upon local signs; for the stimulus from an object a hundred miles off reaches the same identical rod or cone in the retina as the stimulus from an object a few inches away if the two lie in the same line from the eye. Depth perception is due to the combination of certain non-visual data with visual impulses, just as surface perception is due to the combination of kinesthetic impulses with impulses from the external receptors. We may divide these non-visual data into two classes: *uniocular* and *binocular* factors.

(1) **Uniocular Factors.** — The two eyes normally work

together, and this coöperation assists greatly in depth perception. But even when one eye is closed, or if its functions are impaired, the distance of objects is still perceived with fair accuracy. Several distinct data assist in uniocular determination of depth.

(i) Accommodation Sensations. In examining the structure and functions of the eye, we noted that the lens bulges or flattens according as the object which we are fixating is near by or far off. This change in the lens is accomplished by a special muscle called the ciliary or accommodation muscle. Its contraction or relaxation stimulates kinesthetic sensations.

Any specific amount of contraction of the accommodation muscle yields a certain definite intensity of kinesthetic sensation. Hence, when we focus the eye for objects at a certain distance the kinesthetic sensation stimulated by the state of contraction of the accommodation muscle furnishes a datum for perceiving that distance. Thus the stimuli affecting any group of retinal points are perceived as near or far according to the *accommodation sensations* which accompany them.

These data assist only in perceiving a limited range of depths. In the normal eye the lens is entirely relaxed when we fixate for about 6 to 10 meters (according to age) and there is no further change of accommodation beyond that limit, no matter how far off we look. The near-by limit also varies with age; for persons of 20 years the near-point is 10 cm. We cannot contract the accommodation muscle sufficiently to focus the rays coming from points nearer the eye than this.

(ii) Sharpness (Clearness) of Outline. Owing to the density of the earth's atmosphere and the solid particles which it contains, objects at a distance do not show up in such clear outline as objects near by, and their surface differences are apt to be less distinct. Objects are perceived as close to us if they are sharply outlined; they appear far off if their features

are very indistinct. This is an important factor, but its data vary greatly and are frequently subject to wrong grouping. We misinterpret distances in looking through an unusually clear or unusually dense medium. In Colorado, mountains 30 or 40 miles away seem only a half-hour walk distant. Objects seen in a misty atmosphere loom up large, because they appear much farther off than they really are.

(iii) SUPERPOSITION. An object which is nearer the eye than a second object covers part of the more distant one if the two lie in the same straight line. Hence, when we see the outline of some familiar object broken into by another, the former looks farther away than the latter. This effect, called *superposition*, is of great use in perceiving the relative distance of objects, but not their actual distance. It is of no help in measuring depth except as other factors coöperate.

(iv) SHADOWS AND SHADING. Unless the light falling upon an object strike it perpendicularly, any projection or indentation will cause shadows upon its surface. When light strikes the human face from the right, the nose casts a shadow on the left cheek, the mouth is in shadow, etc. The shading is interpreted as denoting that the various features are at different distances from the source of light and from the observer. This factor gives the finest of all depth distinctions. More than any other it enables us to see *in perspective* and *in relief*. The landscape appears to us not as an irregular *surface* but as a three-dimensional grouping of *solid objects*. So powerful is this factor that we tend to interpret the flat surface of a painting or photograph in terms of depth. The objects project out and recede back from the plane of the canvas or paper. Looking at the stage in a theater, we perceive a cottage in the background at least two or three miles away, although we know perfectly well that the city street is less than 400 feet back of the foot-lights.

(v) SIZE AND SHAPE OF FAMILIAR OBJECTS. When objects of a certain kind are all of about the same size, the size of the

retinal picture gives us a clue to the distance of any one of the class. For example, the height of grown-up human beings varies ordinarily only a few inches from an average of 5 feet 7 inches. When we perceive a human figure standing or walking, if the size of the retinal picture is small the man looks distant, if large he looks near by. Houses differ considerably in size, but the windows and the height of each story are fairly uniform; we perceive the distance of a house accordingly. Vehicles, animals, trees, fences, and other familiar objects afford similar indications.

This factor may give rise to misinterpretation of distance. A miniature house on the stage is perceived as a full-sized house in the distance. A child dressed in adult clothes appears to be a grown man farther off.

Not only the size but the shape of any familiar object gives us indications in regard to its position. Book covers are usually rectangular; when we see a book lying before us whose cover has two acute and two obtuse angles we project one of the acute corners farther away from us than the other. [See Fig. 57.] Much of the perspective effect in paintings and pictures depends upon these data.

(vi) Relative Motion of different parts of the landscape. When we travel through the country on a train or other conveyance, objects near at hand pass by much more rapidly than distant objects. If when we are standing we move the head to right and left the same phenomenon occurs in lesser degree. In both cases we receive indications of the relative distance of objects in perspective from their relative rate of motion across the field of vision. For the normal individual this datum furnishes little aid to depth perception, but to one who depends entirely upon uniocular vision it is the most important factor in giving perspective to the landscape.

(2) **Binocular Factors.** — Two additional factors enter into our perception of depth when the two eyes work together as a single instrument.

(i) Convergence. When we look first at an object near by and then at an object some distance directly behind it, the two eyes do not act together in the same way as in ordinary eye movement. Either one eye remains fixed and the other turns slightly outward (that is, away from the nose); or both turn together in an outward direction. These eye movements are accompanied by kinesthetic sensations. The sensations which arise when both external muscles act, or when the external of one eye acts and that of the other eye remains fixed, are different from the sensations which accompany the ordinary horizontal eye movements, where both eyes turn to right or left simultaneously.

The phenomenon of fixating the two eyes upon a single point is called *convergence*. The kinesthetic sensations accompanying change of convergence furnish indications of depth. They aid us in perceiving the distance or depth of the point upon which the eyes are converged. To the normal individual, who uses the two eyes as a single instrument, this supplements to an important degree the uniocular indications; but its value is limited to distances of not more than 100 feet; beyond this there is practically no change in the angle of convergence.

(ii) Binocular Parallax. If we hold a piece of cardboard between the two eyes with one edge toward us, the left eye sees one surface of the cardboard while the right eye sees the other surface; the two visual fields are quite different. If we hold a ball near the eyes, the right eye sees a little farther around to the right. Any curved surface within a certain distance from the body is seen slightly differently by the two eyes.

A blind person finds difficulty in understanding why this double picture does not result in confusion. As a matter of fact, the two different visual pictures do not clash under ordinary conditions; they combine together and give a single, definite impression. The differences between the two pictures merely cause the object to 'jut out' in the field of perception.

This factor, called *binocular parallax,* adds the finishing touch to perception of depth. It gives the appearance of projection (relief) and solidity to visual objects.

The rôle of binocular parallax may be studied by means of the stereoscope. If we look at two photographs of an object or landscape through a stereoscope, the resulting picture appears flat if the two photographs are exactly alike, but it looks convincingly ' solid ' if the two have been taken from slightly different positions.

Central Processes in Visual Projection. — The perception of depth involves the coöperation and combination of a greater variety of sensory elements than enter into surface perception. Some of the factors just discussed involve other operations than sensation. The perception of an object's distance based upon the size of the retinal picture involves retention of many past perception effects. When we perceive that a book is lying at an angle because the corners are distorted, the experience involves past perceptions of many different tilted positions. But the experience of depth is not an ' inference ' — it does not arise *after* the object is perceived. We perceive the size and the tilt *at once.* This can readily be verified experimentally. The immediateness of the depth experience indicates that the coöperating data combine with visual data before (or when) the impulse reaches the secondary visual center.

The most difficult feature of the process to understand is how we come to have *one single* perception, not two, when each of the two eyes has a complete retinal picture of the entire field except the blind-spot area. This is partly explained by the course of the optic nerve. At the optic chiasm (Fig. 35) the fibers from the *inner* (nasal) half of each retina cross to the opposite side of the brain; those from the outer half do not. Hence the fibers from the left half of each retina terminate in the left side of the brain, those from the right half in the right side. Accordingly the two (similar) stimuli from the corresponding points in the two retinas arrive simultaneously at

neighboring points in the visual center. Just how these pairs of corresponding central points are connected is not yet known. But that a mechanism of some sort has evolved for connecting them is indicated by the fact that we *do* see objects singly when the eyes are properly focused.[1]

Another difficulty (which is more philosophical than psychological) is how we seem to see objects "off at a distance" when the perception process actually takes place in the brain. So far as perception is a mental state, this is readily explained. The projective character, like the two-dimensional character of perception, is a specific kind of *transformation*. A 'projected out' quality is added to the component sensations by the several factors discussed above, in much the same way that a 'spread out' quality is added to the sensation group in surface perception. Our projection of visual experiences means only that we project most of these visual pictures *beyond the visual picture of our own body*, which forms part of the visual field.[2]

Projection in Other Senses. — Distance perception and projection are more developed in the distant senses than in the contiguous senses, where the stimulating object lies close to the body. While projection is most highly developed in sight, it appears to a considerable extent in smell and hearing. A given odor is projected into the rose, seaweed, frying bacon, or other objective source of the stimulus. It is perceived not in our nostrils but in the outside object. Sounds are localized outside of the head and often at a considerable distance.

The actual distance of odorous objects or sounds is not perceived with any such degree of precision as in sight. If we possess the sense of sight we usually project odors into the objects which we see, and measure the distance of the source vis-

[1] The *single* perception of two corresponding points is a case of *fusion*. The same operation occurs in binaural hearing of identical sounds.

[2] See Appendix, "Perception of the External World," p. 416.

ually. The projection of sounds is assisted by training. Certain sounds occur ordinarily within a certain range of intensity. If they are heard softer or louder than usual we localize them far off or near by, respectively. The muscle sense, while it coöperates in visual projection, does not build up a set of projective relations of its own in normal, seeing individuals.[1]

The cutaneous senses (warmth, cold, touch) furnish a few independent indications of depth and projection. If we put our hand near a hot stove we 'feel' the warmth in the region beyond, not in the skin. The same thing is observed in holding the hand near a cake of ice. Ordinarily when this occurs our eyes are open and there is visual projection also. But even with closed eyes some temperature projection occurs. In touch, which is well developed for surface perception, projection is only slightly developed. Indeed, one is apt to imagine that it is altogether lacking. But careful observation will furnish many instances.

Projection in touch usually occurs when a rigid object connects the source of stimulation with our tactile receptors. When we write with a pen we feel the point of the pen touching the paper. When we cut with scissors the touch sensation is projected to the place where the cutting occurs. When we

[1] The space perception of the blind is radically different from that of normal man and deserves more careful investigation than it has so far received. The blind perceive all sides of a solid object simultaneously. They perceive the back or far side of things as well as the front. Their projective process is of a different type from ours. Miss Lydia P. Hayes of the New Jersey Commission for the Blind, who had been blind from the age of 8 and was gradually recovering sight after an operation, told the writer of the puzzling impression she received when first looking at a baseball. She did not recognize it at once as a sphere; it seemed "all bunched together." She had been accustomed to perceive *all around* a ball at once — not simply *one half* bounded by an edge, as it appears visually.

Miss Hayes says: "The blind have no conception of perspective and convergence. I still find after several years that I think I cannot get by objects, and it seems as if buildings must fall upon me. Soon after the first operation I refused to go to the back of a restaurant because it seemed to me it was so narrow at the rear we could not get air enough, and was much surprised to be told that the room was of the same width throughout."

walk we feel the pressure of our soles on the ground, and in using a cane we feel the tip of the cane where it touches the ground. Most singular of all, when we dig with a spade we feel the impact of the spade underground when it strikes a stone.[1]

These phenomena indicate a general tendency in perception to *project a sensation as far out from the body toward the source as the data warrant.* Projection is a type of transformation which the sense data undergo in all combinations involving depth. Visual projection surpasses that of other senses because the visual stimuli afford greater opportunity for the operation. The light waves are very minute, they reach the eye from enormous distances, and the receptor itself is so developed that it is capable of very fine local discrimination. But the projective process occurs to some extent among all sense data. Even our systemic sensations are projected from the brain centers to their source in the receptors within the body, and kinesthetic sensations of effort are often projected into objects, so that even inanimate things seem to possess power and strength.

d. Apperception (Focused Perception). — When a group of simultaneous stimuli affect one of the external senses, some of the resulting sensations enter into the perception more clearly and vividly than others. Usually there is a 'focus,' comprising certain elements which are especially clear; other components of the perception are fairly vivid, and still others are quite indistinct or wholly unnoticed. This unevenness in the perception is partly due to differences in the intensity of the stimuli. A loud sound usually occupies the focus of perception, while very faint sounds which accompany it are unnoticed. A bright-colored pattern stands out prominent, while the dimmer background is scarcely observed at all.

In most perceptions there is also an unevenness which arises during the combination process and may be quite inde-

[1] In these illustrations the word 'feel' means a state of perception.

pendent of the intensity of stimulation. When we look at a human face we do not observe clearly each individual feature. Probably the eyes, nose, and mouth stand out most prominent, the ears and chin and the arrangement of hair are noticed somewhat, while the curves and shading of the cheeks may escape attention altogether. These differences of vividness among the elements composing the perception are not due to differences in intensity of the several stimuli, but depend upon the way in which the elementary nerve impulses are combined at the center into a complex perceptual state.

This phase of the perceptual process is called *apperception*, or focused perception. It is apparently due to variations in the metabolic condition of the central synapses, which alter the intensity of some of the sensory impulses and produce changes of vividness in the components of the perception. The focusing process is popularly called " turning the attention " to an object or to some of its details.

In sight the apperception process is assisted by the mobility of the eye and the high efficiency of the center of the retina. Objects which stimulate the fovea give a clearer impression than those at the periphery, because the foveal receptors are more closely packed together and admit finer discrimination than the rest of the retina. Since we are able by an ocular reflex to turn the eyes so that bright objects perceived peripherally will stimulate the fovea, the foveal region of the retina comes to be the part most frequently used in visual perception; its central connections are generally in the most favorable metabolic condition. The popular idea of ' turning ' the attention is based upon this act of turning the eye, which plays such an important part in visual perception.

In touch the focusing process is often assisted in a similar way. The finger-tips and the tongue are regions of fine discrimination; objects are apperceived by touching them with these members. In hearing we sometimes focus by turning

the head, and in smell we intensify certain sensations by drawing a long breath.

Apperception occurs also without these motor aids. One can learn to observe out of the 'corner of the eye,' so that an object near the periphery is attended to without turning the eyeball. We pick out certain agreeable or disagreeable odors from a mass of smell sensations. In hearing there is the classic instance of the doctor who is aroused at night by the front-door bell, while his wife sleeps calmly on; when the baby cries the wife jumps up and the physician slumbers undisturbed.

The increased vividness of some components is only half the story. There is a 'defocusing' as well as a focusing. In the grouping process some of the synapses are partly blocked, and the impulses along these paths lose in strength as they pass into the higher neuron; the corresponding portion of the impression is less vivid than the intensity of its stimulus warrants. The process of apperception includes both of these phases, focalization and defocalization, attention and inattention.

A special problem in connection with apperception is the number of objects which can be perceived distinctly at once; not the total number of components in the perception, which may be indefinitely great, but the number of 'vivid groups' which are marked off as separate objects. This is called the *span of attention.* Experimental investigations have given different results, and it appears that the span depends upon several factors. Under ordinary conditions from 6 to 8 objects are clearly distinguished simultaneously. The number may be increased with practice to about 15.

e. Object Perception. — Objects in the environment usually affect more than one of the senses. They provide stimuli of various sorts which act upon several types of receptor at the same time. An orange (which for some reason psychologists generally select for illustration) may affect at once the eye, the skin, the muscles, the nostrils, and the taste

bulbs. As a result we see, touch (' palp '), heft, smell, and taste it, all at the same time.

Stimuli from *different* objects which affect different receptors usually tend to *inhibit* one another. When we are reading a book the conversation about us and other noises pass unnoticed, and when we listen to conversation the objects about us may be lost to view. But in the case of simultaneous stimuli from the *same* object the opposite is true. The visual, tactile, kinesthetic, olfactory, and gustatory sensations induced by an orange *combine into one single perception.* This type of mental state is called perception of objects, or *object perception.* In discussing surface and depth we spoke of 'perceiving objects,' although only *one* class of receptor was involved. This is in fact the beginning of object perception; but perception of objects in the environment is only completely ' rounded out ' when the mental state includes several sorts of data — sight, kinesthesis, and touch, for instance. The distinction is more important than one might realize. In certain pathological conditions the kinesthetic sensations are cut off. The patient reports that the world which he sees does not "look real." He lacks object perception in its highest form.

In object perception the space relations in the several senses dove-tail together. We feel (palp) our hand as situated in the same place as that in which we see it. The space data from the various sensory sources are *integrated.* Our field of perception consists of only *one space* — not a visual space, a tactile space, and a kinesthetic space. This is brought out strikingly when the normal relationship of the senses is disturbed. If we look at our hand through a reversing lens we feel the fingers in a different place from where we see them. In using a microscope we push the slide in one direction to produce visual movement in the opposite direction.

Reintegration of perception under abnormal conditions was observed in Stratton's experiment. Stratton wore a

large reversing lens continuously for 7 days, removing the apparatus only at night, when the eyes were bandaged. The whole field of vision was thereby turned 180° from the normal orientation. With respect to touch and muscle sense his left hand was seen at the right side, his feet above, the lintel of a door was seen below. At the end of the period he found that the space relations were at times almost completely reintegrated to meet the new conditions. He reached for things where he saw them and manipulated implements properly. He felt his hands, feet, and body in the same place and in the same relations as their visual pictures. Only the head, which had not been seen during the experiment, remained partly in the old tactile situation; — its localization was confused and vacillating.[1]

The neural mechanism for object perception is the numerous tracts of nerve fibers which connect the various sensory centers in the cortex. These association fibers make it possible for simultaneous impulses in different centers to pass to some common higher center and combine together there.

The development of object perception depends upon frequent repetition of similar combinations of sensory impulses. If a certain visual impulse is accompanied by various tactile or auditory impressions at different times, there is no fixed mode of combination between them; but where a certain visual perception (e.g., an orange) is always accompanied by similar olfactory sensations, similar touch sensations, etc., their combination into a definite sort of perception becomes more and more fixed. In other words, object perception begins with the most common objects about us, and develops constantly as our habitual experiences extend to a greater variety of things and beings.

[1] The oldest recorded piece of work in experimental psychology, Aristotle's experiment, is in the same general field. Aristotle noted that if the middle fingers are crossed and a small object be placed between them (the eyes being closed) the object appears double.

Object perception is usually accompanied by certain ideational data in addition to its sensory components. Our perception of an orange commonly includes a taste component, even when the orange is uncut; iron 'looks heavy,' while aluminium 'looks light.' These ideational components are due to the fact that corresponding taste or kinesthetic sensations have in the past frequently accompanied visual sensations similar to those now present. In adult life practically all of our perceptions of objects are tinged with imagery due to past experiences. An 'object experience' includes the various impressions which we receive or have received through the several senses from this object or from objects like it.

The *retention* factor plays an important part in the formation of object experiences. It is due to the persistence of past effects that habitual sensations combine more readily than isolated sensations, and that ideas unite with present sensations. *Modification* is also an important factor in determining the quality of object perception. The same object or group of objects appears different after it has been repeatedly perceived. An example of this may be readily observed if one has been living in a new town for three or four years. Apart from any changes which have actually taken place in the buildings or landscape, his perception of the place is quite altered; the difference is due to the growth of new object perceptions, and especially to the modifications produced by ideational elements of the 'memory' type.

In certain individuals a peculiar type of object perception occurs, in which ideational components of an arbitrary sort enter into the mental state. These persons report that certain sounds assume a pronounced visual tinge. One vowel sound looks blue, another red, etc. According to the reports these mental states are perceptions, not merely ideas which follow perceptions. The experiences are sometimes called *colored hearing;* but similar perceptions occur in which other senses are involved, so that this type of object perception is

more properly termed *synesthesia*. Synesthesia is probably due to certain chance groupings of sensations which occurred early in life and have persisted in spite of their lack of basis in external stimulation. These phenomena are not pathological, but on the other hand they are not in line with the ordinary development of object perception.

f. Perception of Events, Time, and Rhythm. — Most stimuli persist for some length of time, and the sensations which they produce persist also. When an object moves or changes or disappears, the impulses in the higher centers do not immediately cease nor alter all at once; there is usually a certain period during which the old perception is fading away and the new perception is beginning. In other words, successive perceptions dove-tail together; we perceive at one and the same instant both the in-coming and the out-going events. The ' now ' of perception is not the same as the physicist's conception of the ' present.' It is not a thin knife-edge separating the past from the future, but a fair-sized interval of time.

According to careful experimental investigation the *perceptual present* (sometimes called the ' specious present ') is a duration of about 6 seconds (Titchener). All impressions within this period of time are present to us *at once*. This makes it possible for us to perceive changes and events as well as stationary objects. The perceptual present is supplemented by the ideational present. Through the combination of perceptions with memory images (ch. xiii), entire days, months, and even years of the past are brought together into the present. Thought (ch. xv) extends our present experience still further to include centuries and eons of time, both past and future.

The gradual appearance and gradual fading away of perceptions form the basis not only of our experience of events, but of our experience of duration. As a perceptual experience, the range of each of these periods is very limited. The

generalized experience of time relations (often called *time perception*) is not a matter of perception but of thought.

The unevenness of successive experiences gives rise to a special type of perception called *rhythm.* Rhythm occurs almost exclusively in connection with auditory data. It is due to the succession of more vivid and less vivid perceptions. These group themselves into a series consisting of *accented* and *unaccented* elements, which occur alternately. The accentuation (or vividness) is generally due to some character of the stimulus. In poetry or music the accented syllable or beat is made prominent either (1) by greater intensity (loud, soft, soft, loud, soft, soft), (2) by longer duration (𝅗𝅥 ♩ ♩ 𝅗𝅥 ♩ ♩), or (3) by some specific quality; if the bass is C, E, E, C, E, E, this serves to accentuate the first and fourth clangs. Two or more of these factors often coöperate to produce rhythm, and at times the rhythm may be due partly (or entirely) to central factors. One may readily weave a rhythm pattern into the uniform ticking of a clock. The rhythm experience, like the generalized experience of duration, usually involves imagery or thought.

A number of different tones or clangs, arranged in rhythmic series, are grouped together into a perceptual unit called a *tune.* A familiar tune, such as the *Star-Spangled Banner* or the *Marseillaise,* comes to have an individuality of its own. Our experience of one tune differs from that of another in much the same way as our perception of a table differs from that of a chair. The growth of this individualizing process may be readily observed. When one first hears the army bugle calls they appear as mere tone-successions, only vaguely differentiated from one another. After a time the tattoo, reveille, and others come to be as distinctly individual as the familiar visual objects of every-day life.

Series of data from the other external senses, especially sight, are grouped together in a similar way. Familiar acts which we see others perform consist of a succession of visual

sensations, but they are perceived as single *events.* Such, for instance, are walking, running, stooping, eating, speaking, gesticulation. In the same way the fall of a leaf, the turning of a wheel, the lashing of surf, and all the various activities of animate and inanimate nature are perceived as events.

There are more ideational components involved in event perception than in object perception. The experience of present objects consists almost wholly of sensations, while event experience includes more and more of imagery as the period of time involved is lengthened. When we see some one smile our perception is altogether sensory; in our perception of a horse-race the sensations toward the end are interwoven with many memories of the preceding stages. In every case the basis of the experience is sensory; the mental state is perceptual.

g. Perception of Differences (Discrimination). — Simple motor discrimination does not involve the activity of higher nervous arcs. An impulse may be distributed directly into various motor paths through the lower centers. Even a reflex may give a discriminative response. But the type of discrimination which we observe subjectively is a perceptual state; its arc goes through the higher centers.

When we perceive differences of intensity or quality between two sensations, the two sensory impulses are brought together in a perception center and the distribution of the motor impulse is regulated by the intensity or mode of the sensory impulses. If we compare the intensity of two sounds our motor response is the spoken word 'louder' or 'softer' (or some equivalent pair of responses). Which word we utter depends upon the order in which the two stimuli are presented. The neural operation in the centers is discrimination, or *perception of difference.* Two perceptions may be discriminated not only as to quality and intensity, but in respect to duration and extensity.

A large part of the experimental work in psychological lab-

oratories has been concerned with perception of differences. Almost all of the investigations in psychophysics, which are summed up in Weber's Law,[1] use perceptions for their material.

Table XIV shows the values of the discrimination constant for intensity in the several senses as determined by experiment. The fractions indicate in each case that the intensity of the stimulus must be increased by that proportion of itself to produce a "just perceivable difference." This fraction is called the limen or *threshold of difference* for the given sense. Fig. 58 shows the increase in the stimulus for each 'step' in the perception of differences of noise intensities. The curve for touch is similar in form but flatter; the muscle sense curve is flatter still; the visual curve is flattest of all. The flatter the curve, the finer is the discrimination.

TABLE XIV. — VALUES OF THE WEBER CONSTANT

Sensation	*L.P.D. Intensity*	*Individual range*
Visual (light)	0.01	0.015 to 0.005
Auditory (noise)	$0.33\frac{1}{3}$	
" (tones)	0.15	0.20 to 0.125
Olfactory	0.25	0.33 to 0.25
Gustatory	0.25	0.33 to 0.25
Tactile	0.05	0.10 to 0.033
Warmth	$0.33\frac{1}{3}$	0.33 to 0.25
Cold	$0.33\frac{1}{3}$	0.33 to 0.25
Kinesthetic	0.025	0.05 to 0.013

Each fraction denotes the *proportion of the original stimulus* which must be *added to it* in order that the sensation may be just noticeably greater.

The just perceptible differences of color hues and auditory tones may also be determined experimentally. Their values are expressed in terms of the wave lengths of the stimuli. They do not follow the Weber Law.

Truth and Illusion in Perception. — Our perception of the qualities and relations of external objects and events is far

[1] Cf. chs. v, xi.

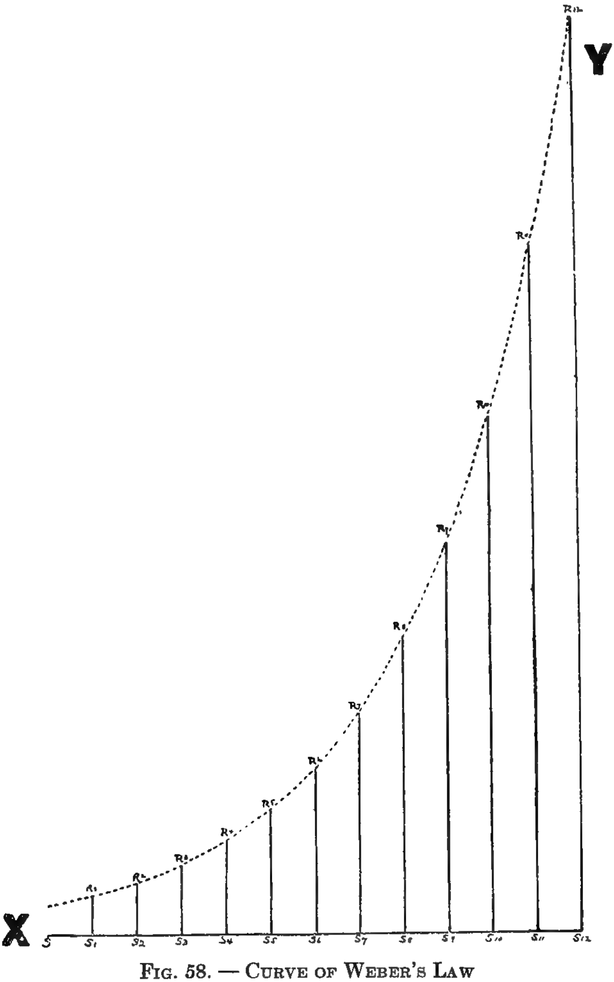

FIG. 58. — CURVE OF WEBER'S LAW

Form of the curve for intensity of sound; constant = $\frac{1}{3}$. Successive "just perceptible" increases of sensation are indicated by equal distances along the X axis at points S_1, S_2, etc. Corresponding values of stimuli are represented by the lines $S_1 - R_1$, $S_2 - R_2$, etc.

more exact than would be expected from a consideration of the sensory data. The fact that the visual receptors are located in one region, the auditory receptors in another, the

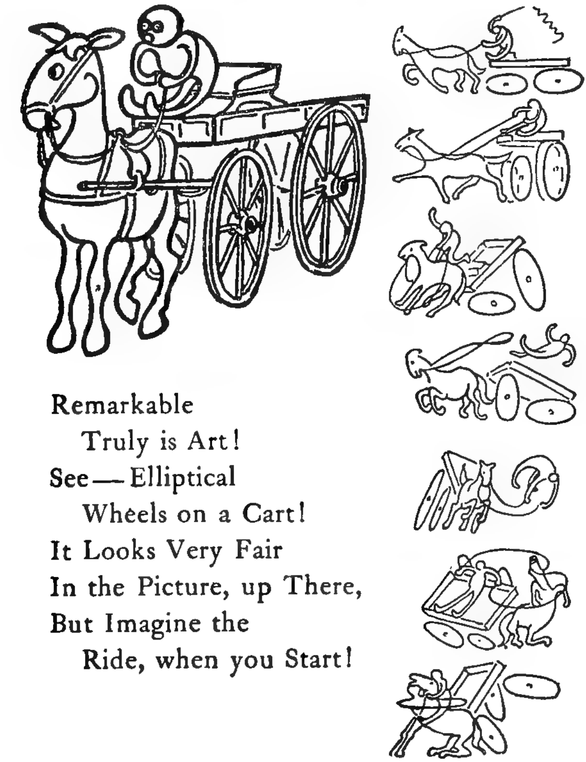

FIG. 59. — A STUDY IN PERSPECTIVE

The cart-wheels appear circular, though they are actually drawn as ellipses. The smaller sketches show what would happen if the wheels were really elliptical. [From Gelett Burgess.]

taste bulbs in a third, might lead one to suppose, if he had no senses of his own, that a human being would see things in one place, hear them in another, and so on. The complicated

paths of the nerve fibers to the brain and the separation of the various sense centers would serve to confirm this supposition. But as a matter of fact we normally project all the various sense data from any given object into the same set of space relations. We perceive it as *one* object, not *many.*

It is certainly not remarkable, considering the intricacies of the perceptual process, that the outcome is sometimes inexact — that our mental states do not always present the true relations of objects in the environment as determined

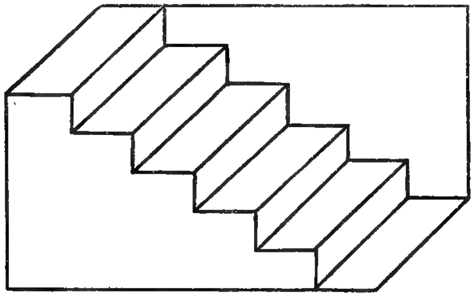

FIG. 60. — STAIRCASE ILLUSION

At first sight this appears to be a flight of stairs. It can be reversed by focusing on the upper jagged line, so that the upper-right corner appears nearer than the lower-left; the figure then looks like a cornice, or like cellar stairs seen from underneath. [From Jastrow.]

by physical measurements. Perceptual grouping is based upon habit, and when present sensory data conflict with firmly established types of experience an 'untrue' perception arises.[1] A perception which does not correspond to the situation in the environment is called an *illusion.*

[1] Philosophers have worried considerably over the 'truth' and 'falsity' of sensation and perception. The psychologist does not regard this as a disturbing problem at all. From external object to perception there is a long road to travel — first the stimulus, then the sensory impulse, the sensation, and the grouping of impulses. If there is a defect in any portion of the pathway, the percepton is affected. All perceptions are more or less 'untrue' — they are not 'copies' of the external objects — they represent objects imperfectly at best.

Some familiar illusions have already been noted: on a misty day objects look larger or farther off than they actually are; a well-drawn 'flat' picture is seen in perspective.

The wheels of a real cart are not elliptical as shown in Fig.

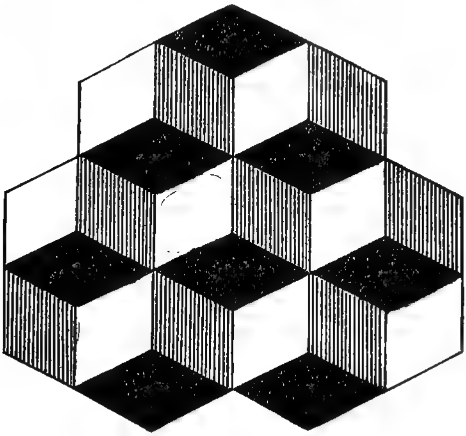

Fig. 61. — Illusion of the Cubes

Either six or seven cubes are seen, according to the perspective. [From Jastrow.]

59; we perceive both real wheels and pictured wheels as circular. In some cases the perspective interpretation of a picture is variable; sometimes one point in the field appears nearer, sometimes another. Two examples of this, the staircase and cube illusions, are given in Figs. 60 and 61.

Certain illusions show the influence of the various factors which coöperate in the perception process. In Fig. 62 the outline of the letters is completed by ideational elements. (Observe the effect of turning this figure upside down.) In the footnote on page 261 are two misprints which many readers will overlook.

Fig. 63 illustrates the conflict of inconsistent interpretations; we may see the creature either as a duck or as a rabbit.

A well-known type of illusion is the puzzle picture, in which

FIG. 62. — FILLED-IN PERCEPTION

Hold the book at a distance and the outline of the letters appears complete. The missing lines are supplied in perception.

some object is obscurely outlined among the more prominent features of the drawing. Once the 'hidden' object is per-

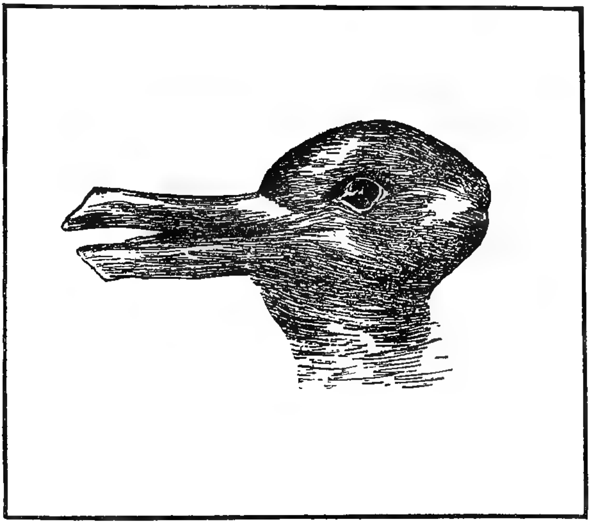

FIG. 63. — DOUBLE PERCEPTION

The rabbit-duck. [From Jastrow, after Harper's.]

ceived it tends to become focalized. Fig. 64 appears first to

be an ordinary diagram of the brain; later the "children of the brain" become the center of attention.

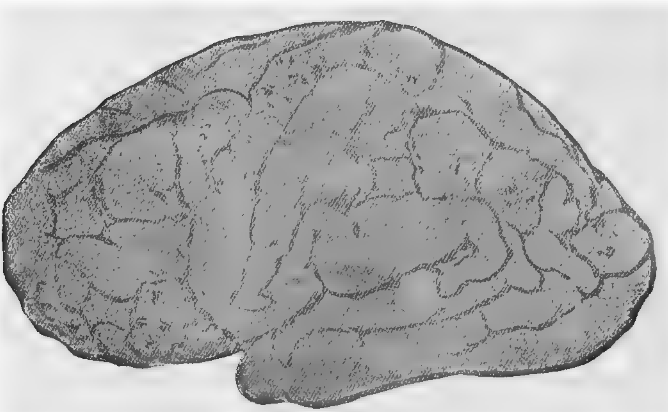

Fig. 64. — Hidden Perception

Children of the brain. [From Titchener, after Gudden.]

Certain illusions are due to eye movements which are not properly taken into account in perception; the kinesthetic data furnish a report of the actual eye movements, which are greater or less than the distances they are supposed to cover; to this extent the perception does not tally with the external object or event. Many illusions of this sort have been discovered. Two examples are given in Figs. 65 and 66. In the Müller-Lyer illusion the left distance is perceived as considerably longer than the right, though the two are really equal. In the Hering illusion the two horizontal lines are really parallel, but they are perceived as 'bow-legged.' In the Müller-Lyer figure the eye travels not from apex to apex, but from some point within the first angle to a corresponding point within the second angle, making one distance appear longer than the other. In the Hering figure the eye is diverted from a straight path by the converging

cross-lines, making the horizontal lines appear to curve in the opposite direction.

We may mention here the effect of changing the orientation of objects, though this is not so much an illusion as a

FIG. 65. — MÜLLER-LYER ILLUSION

Distance between apex of left and apex of central figure appears longer than between central and right. The two distances are equal.

measure of the *direction* factor in surface perception. An unsymmetrical building or landscape in a reversed photograph does not look strange unless we are very familiar with

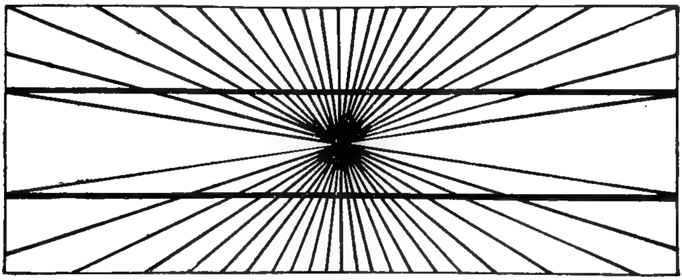

FIG. 66. — HERING ILLUSION

The horizontal lines appear to bend apart in the middle. They are parallel.

that particular building or scene. Human beings and animals (being usually symmetrical) are easily recognized in a 'mirror-picture.' But reversed lettering, especially 'mirror-script,' appears a fantastic jumble. [Fig. 67.] This is due to a special factor of asymmetry in the mental operation of reading.[1] A curious change in perception occurs if we look at the landscape with the head upside down.

[1] See ch. xv.

Relation of Perception to Sensation. — We are now in a position to distinguish between perceptions and sensations. Perception, like sensation, depends upon present stimulation of the receptors; its chief components are derived from the external senses, and its characters are determined originally

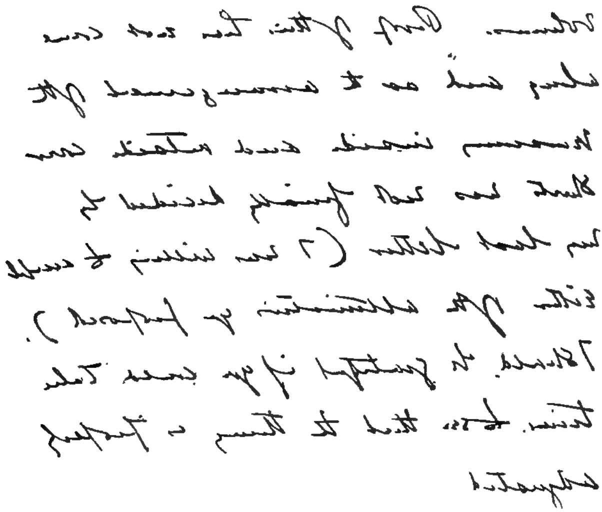

FIG. 67. — PERCEPTION OF MIRROR SCRIPT

Unless one is practiced in reading reversed writing, it is difficult to recognize a single word in the above. Hold it to a mirror and the writing is quite plain.

by the quality and intensity of the stimuli. To this extent sensation furnishes the basis for the perceptual processes.

But in addition to its sensory components perception depends upon several central factors:

(1) Summation of many separate impulses into one; that is, the *combination* (fusion and colligation) of separate sensations.

(2) Metabolic changes in the separate impulses; that is, the operation of a focalizing factor which produces *vividness* in

certain components and obscurity in others, often quite out of proportion with their sensory intensity.

(3) Modification of the resulting impulse; that is, a *transformation* of quality due to the mutual interaction of the components, including the ideational components which enter into the perception.

In all these respects perceptions are determined less by the specific stimuli and more by the central mechanism than sensations. Yet as we have noticed, perceptual states correspond more closely to the 'general situation' in the outer world than their components.

The two characters of sensation, (1) *quality* and (2) *intensity*, are carried over to perception. In addition, perception has three characters of its own. (3) *Vividness*, a quantitative variation which is independent of the stimulus and is due to the central focalizing process, or attention. (4) *Extensity*, due directly to the grouping together of impulses from separate nerve fibers on the basis of local signs, and indirectly to the space relations of external objects. (5) *Duration*, due to the prolongation of stimulation and of the nerve impulse.

Physiology of Perception. — The manner in which sense data are combined into perceptual experiences depends primarily upon the inherited structure of our central nervous system. Sensory neurons which lie near together in the brain and connect up with a single higher neuron, tend to furnish group impressions. Thus a number of visual sensations which occur simultaneously may be joined together, forming a single mental state which is very like a sensation. The same is true of auditory impressions and other types. The sight of a red disk, the sound of a complex chord, belong to the simplest type of perception; the grouping probably takes place in the primary centers. Perceptions which involve various senses are brought about by the operation of association fibers which gather the separate data from sev-

eral centers into a higher center. This results in perception of objects.

The perception of space relations develops because impressions from different local receptors usually occur in certain definite sequences, and because these sequences are distinguished by certain kinesthetic accompaniments. Both surface perception and depth perception are built up in this way.

Both the grouping process and the familiarity coefficient are due to retention traces in the central neurons, which have been consolidated by frequent repetition of similar perceptual experiences. In adult life our perception of every common object and event is something more than an experience of the present sense data; the central state is consolidated and supplemented by data from past experiences. Our perception of a friend's face when we observe it in full front, includes a vague impression of his profile and the back of his head. The more frequently we observe the same object or occurrence with slight variations, the fuller and richer does our perception of it become. Absence of these ideational components hampers the perception process, as illustrated in reversed handwriting.

The highest development of perception, then, depends not only upon the presence of a mass of association fibers connecting the various sensory centers in the brain, but upon the formation of specific connections by means of these fibers, and the retention of such effects.

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PRACTICAL EXERCISES:

Examine how far your depth perception depends upon each of the eight factors mentioned in the text.

Test the 'staircase illusion,' i.e., eye movement, volition, time, etc., in changing from one perspective to the other.

Glance for one second at a shop window as you walk by. What objects did you perceive? Repeat for several shops and note *number* of perceptions obtained for each.

Analyze the perception of an apple into its components.

CHAPTER XIII

PRIMARY MENTAL STATES (*continued*)

2. Imagery

Nature and Classes of Imagery. — An *image* consists of groups of ideational elements. The grouping of component ideas into an image is similar to the grouping of sensations in perception. The quality of an image is not determined by the mode of present sensory impulses; it is determined by the retention trace.

Images are divided into two main classes, according to the nature of their components.[1] (1) Images in which the chief components are traces of former sensations. These are called *memory images.* (2) Images in which the components are modified traces. These may be grouped together as *synthetic images,* but they really comprise several distinct kinds, differing according to their relation to the environment. Altogether we find the following classes of imagery:

Memory images
Free images
Anticipation images
Imagination images (fancies)
General images

We shall find later that imagery develops in man into a higher type of experience called thought. Psychologists often group together the various types of experience based upon external sensations — perception, imagery, and thought. They are called the *intellectual functions,* or cognition. While

[1] The term *image* is often used rather loosely. An after-sensation is improperly called an after-image. The retinal picture is frequently called the retinal image. In popular usage imagery is applied almost exclusively to visual imagery — leaving tactile, kinesthetic, and auditory imagery entirely out of account.

it is important to recognize the relationship between the externally derived mental states, due to their common origin, the name should not lead us into assuming that a special 'cognitive faculty' exists.

a. Memory Images. — The popular notion of memory is based upon too close an analogy with perception. Objects in the environment continue to exist even when we do not perceive them. Popular psychology assumes that 'memory objects' (memory images) persist in much the same way. It is true that something remains in the brain after the sensation ceases, which furnishes the basis for future memory images. But what remains is not a 'picture' of the object or event, but merely a record; it is a trace or set or retention effect of some sort in the structure of the neurons or synapses. This trace does not resemble the object, nor is it like the sensation. It is somewhat analogous to a phonograph record, where the tracings bear no resemblance whatever to the words or music, but bring about a reproduction of these effects when the needle and diaphragm are properly applied.

Even when this trace is re-excited the result is not always a memory image. If the new impulse is intense when it passes into the higher central neurons the structural trace merely adds one more component to the perception. An example of this is the taste which accompanies the perception of an uncut orange. When the same complex stimulus is repeated several times, the effect is not to transform the perception into an image, but to modify slightly the present perception. This slight modification is called the *feeling of familiarity*. We observe it when we see some person or some building over and over again. In such cases the mental experience of familiarity is not a feeling but an ideational component in the perceptual state.

The memory image is a definite reproduction of some past experience. It is presumably caused by a central impulse entering a higher neuron (or group of neurons) in which a

complex trace has been left by former experiences. If the mode of the new impulse is transformed by the set of this neuron a memory image results. A memory image is more or less complex. It may include some sensory components in addition to the ideational. When I recall some event I may feel elation or regret, which were not part of the original experience. These sensory components are due to present systemic stimuli whose impulses are combined with the ideational components.

The older psychology distinguished four factors in memory: retention, recall, familiarity, and time and space location. *Retention* is a characteristic of nerve structure; it is a condition of memory in precisely the same way that the receptor is a condition of sensation. *Recall* belongs not merely to memory but to all types of imagery; it is a picturesque name for the ideational process itself. Neither of these factors is especially characteristic of memory. The fact that they were considered so by investigators trained in self-observation shows how necessary it is to check up self-observation by means of physiology.

Location in time and space means that the image is 'placed'; a memory image carries with it enough contiguous elements to enable us to fit it into a certain period in our past experience, and into a certain environment. This is characteristic of memory. The temporal location is a different process from the spatial. I recall the spot where I stood near the Capitol when President-elect Wilson drove up with President Taft to be inaugurated. I recall the procession and the crowds, even to the woman standing on the corner with three small children. These are part of the memory image. The more elements it contains, the more definite is its 'space location.'

The temporal location is an 'afterthought.' I place the incident on March 4, because presidential inaugurations occur on that date. If the image is a memory of my last

meeting with some friend, the vividness of the image assists the temporal identification. In general among civilized men the scheme of dates represented by the calendar is the chief factor in determining the time relation; and this involves the thinking process.

An image is recognized as memory when the *feeling of familiarity* attaches to it. If the impulse passing into a certain neuron brings with it no mode different from that of the retention trace, the passage through that neuron is attended with greater ease than if the new impulse alters the mode of the retained trace. That is, a 'revival' of the previous trace without change is accompanied by a familiarity coefficient.

The presence of a familiarity coefficient in the memory image does not always indicate that the image corresponds to a previous sensory experience. The recollection may revive an earlier *imagination* as well as a former sensation. The memory image of any earlier image is characterized by familiarity. We may have vivid imagery of certain family incidents of childhood which have been told us repeatedly; when we recall them in later life, they often appear to be memories of the events themselves; yet we sometimes discover that we were not present on the occasion, or even that they occurred before we were born.

Such misinterpretations of the familiarity coefficient lead to *illusions of memory*. Another type of memory illusion occurs when two memories are combined in one; we remember a remark and attribute it to the wrong person, or we associate some occurrence with the wrong time, place, or general setting. The line between sensation and memory image is not sharply drawn when the stimulus and sensation fade gradually away, especially if an after-sensation follows the sensation. When we look at a bright object and then look away, an after-sensation often appears (ch. ix). After this has faded away a similar memory experience may still

persist. We are not always certain in such cases at what moment the after-sensation ceases and the memory image begins, though a trained observer can usually distinguish between the two forms of experience.

In man the cultivation of the imagery life has developed a 'temporal perspective' more or less analogous to the space perspective of perceptual experience. Our past life presents itself as a continuum in time, extending (or 'protending') from the present moment to our earliest years. Any memory image which occurs at the present moment is projected back to some point in the series. Like space projection this process depends upon certain indications in the present experience. The familiarity coefficient is an important factor in effecting the projection. Another factor in adjusting the time perspective is the nature of the specific image, which 'fits in' better with one period or date than other. The perfection of temporal perspective as a general scheme depends upon successive association.[1] Illusions of wrong projection occur frequently in memory. A vivid memory, such as a great flood or the death of a brother, is placed too close in the foreground. A changed situation in life, such as moving to a new town or starting in a profession, is soon thrown back too far into the past. Many such instances of mistaken memory perspective occur in the experience of everyone.

b. Free Images. — A free image is an image which lacks definite reference to a specific time, space, and setting. We may picture the face of a friend or a tune which we have heard, without special reference to the time and circumstances in which the original perception occurred. Usually the free image results from frequent repetition of substantially the same experience. The effect of this repetition is to weaken the general setting, which is different in each case. The feeling of familiarity on the other hand is strength-

[1] See ch. xvi.

ened. A further effect is to enrich the character of the image. The free image of a friend's face usually includes profile and full front, and the free image of our house may include both inside and out. The free image, then, has many of the characteristics of the memory image, including the familiarity feeling, but it is not a reproduction of one single experience.

c. Anticipation Images. — A free image may be complicated by a 'prospective reference,' that is, it may be associated with some future time and circumstances. It is then called an *anticipation image.* Genetically, we find that the anticipation image appears before the memory image. Imagery seems to have been used in the first place as a means of adaptation to future conditions, and not as a means of recalling and picturing past occurrences. When a baby cries for milk there is probably a faint anticipation image present. In the adult, however, both memory and free imagery attain greater importance. The familiarity feeling is not altogether lacking in the anticipation image, for the free image enters largely into its make-up; but this familiarity feeling is much weaker than in the types previously described.

d. Imagination Images (Fancy). — The imagination image, often called *constructive imagination,* is an image composed of two or more distinct elements — usually a great number. The free image and the anticipation image might be regarded as varieties of imagination; but these types are based upon original stimuli derived from single objects or events, while imagination images are composite. They are derived from a number of separate sensory stimuli, due to different external objects or events. A typical illustration is the image of a centaur, which combines the head of a man with the body and legs of a horse. Here the new experience is obviously derived from two separate perceptions — unless it happens to be the memory of a picture we have seen. The scenes in a novel as we picture them are imagination images,

and so are the earliest plans of an inventor. Imagination images are often called *fancies.*

There is no hard and fast line separating imagination from anticipation imagery. A fancy which is likely to be realized may be regarded as an anticipation image; and when a so-called anticipation is not fulfilled it is classed as a fancy. The distinguishing mark of imagination is the absence of the familiarity feeling; but even this is not an absolute criterion, for the constituent parts of the image are familiar, and if the entire imagination image is repeated, a familiarity feeling gradually attaches to it. The only psychological justification for distinguishing imagination as a separate sort of imagery is that it has no direct relation to our motor activity and to the production of changes in our environment.

It might seem indeed as though the anticipation image were merely an outgrowth and specialized form of imagination. But genetically there is little doubt but that anticipation arose earlier than imagination. The several forms of imagery develop only as they serve to mediate between the creature and his environment. The human child develops anticipation imagery, with its motor components, some time before pure imagination.

e. General Images. — A general image results from the fusion of many similar images into a single experience. In free imagery we have a combination of similar experiences due to the same stimulating object. The general image arises from stimulation by a number of objects which are partly similar and *partly unlike.* Having seen a number of men whose general appearance is the same, but who present certain differences, the child forms an image which is a sort of composite picture of them all. Their common points are present in the focus of the image, some of the different details may appear in the margin. In the same way the general image of a horse is formed when the child has seen a number of different horses; and so for any class of objects.

In adult life the general image is rarely present in pure form. Almost always a word or symbol of some sort attaches to it. The experience then belongs to a higher type of experience, *thought*.[1] The general image or composite picture precedes thought, and occasionally persists in later life if no word has been conventionally attached to a certain experience.

We can investigate the general image by examining a thought and eliminating the verbal symbol. Take for example the general image of *horse*. The image which we have (leaving out of account the name *horse*) is usually based upon some one specimen; it may be an old chestnut mare which we saw frequently in childhood. Attached to this are a variety of differing characters, such as gray and black, long tail and bobtail, stocky and slim, derived from experiences of other horses. These enrich and round out the image in much the same way that the associated elements round out the free image. They are often exceedingly faint, and many details which characterize the original perception are lacking altogether. In other words, our general image of horse, though based upon some particular animal, is not stocky nor slim, it has no distinctive color, etc.; many of the outlines and features which exist in all horses are wanting. The dominant components in the image are those details in which *all horses agree*, and which mark them off from other creatures.

Physiology of the Image. — The nature of the neural process which produces imagery has already been described under ideation. It is supposed to consist in the re-excitation of a neuron which has received a retention trace from past impressions. If the new nerve impulse is powerful, it is but slightly altered by this trace, and the result is a perceptual experience bearing an ideational component. But if the new impulse is weak when it passes across the synapse, it loses its own specific mode and the experience takes on the

[1] See ch. xv.

quality corresponding to the trace. In the latter case the intensity of the experience is far less than that of the original sensation, but it may be quite as vivid and distinct. The distinction between the several classes of imagery depends upon different sorts of grouping of the components, upon the importance of the sensory components, upon the presence of kinesthetic coefficients, and upon ease of neural operation, or familiarity.

Rôle of Imagery in Mental Life. — The relative importance of imagery in the life of an individual depends largely upon his training and general situation of life. At any given instant a perception or other sensory state may go over into a memory image or some other type of imagery if the sensory stimulus is weak and the retention trace is strong. But the proportion of image states to the total mental states varies with one's habits of life. In some individuals we observe a strong tendency to live in the past or in their own thoughts and ideas; in others the ideational life is meagerly developed.

The production of one image rather than another depends in part upon the specific stimuli which affect us at the time, and partly upon the strength of past experiences. The selection of material depends, in the case of memory, upon the three factors of *recency*, *intensity*, and *repetition*.[1] (1) If, for instance, we record as carefully as possible all our memories during one day, it is found that the greater part are recollections of recent events, and that the number decreases as a function of the temporal remoteness of the original experience. (2) More intense or more vivid experiences are recalled in greater number than those which were originally faint. (3) Frequently recurring experiences are recalled in greater number than isolated experiences.

The successful training of memory and imagination depends upon following the principles of acquisition and fixation (ch. vii). It is scarcely necessary to emphasize the

[1] These factors will be treated in ch. xvi.

great practical importance of memory in modern civilized life, and the value of cultivating it.

3. Feelings

Nature of Feeling. — A feeling is a mental state whose chief components are systemic sensations.[1] The data of feeling are furnished either by the pain nerves or by the organic receptors. The combination of systemic elements into actual experiences is similar to the process by which external sensations combine to form perceptions. But the distinction between perceptions and feelings is more than a difference in the sort of receptors which furnish the material. The qualities of the elementary constituents are subject to different kinds of alterations in the grouping.

In perception the specific qualities of the sensations become more vivid in the grouping. Some of the constituents are more definitely marked off and discriminated; others fuse together and the resulting state takes on a new quality which is specific and distinct. On the other hand when systemic sensations unite to form a feeling, the specific qualities of the components become *less distinct;* they merge into the general *hedonic quality* of pleasantness or unpleasantness.

Compare the following experiences: (1) The sight of some painting, such as "Signing the Declaration of Independence." (2) The sound of the final chord of music in an orchestral piece. (3) The agony of an intense toothache or burn or bruise. (4) The pleasant languor accompanying the digestion of a hearty meal.

The first two examples are perceptions. Here the specific qualities are prominent. In the painting the several human

[1] The term *feeling* is often applied to any indistinct sensation. This is an older use. The use of *feeling* to denote sensations of touch ("to feel the texture of cloth") is likely to cause confusion and should be avoided in psychology. *Hedonic* is used as an adjective for *feeling;* hedonic experience, hedonic quality, etc., mean 'feeling experience,' 'feeling quality,' etc. *Affection* and *affective state* may be used interchangeably with feeling.

figures stand out, they are discriminated and localized in space relations. In the musical chord the tone-pattern of the clang is distinct, despite the fusion of the components.

The last two examples are feelings. In the pain experience the quality of unpleasantness dominates over the specific quality of the receptor — whether tooth or skin or muscle. In the languor experience the specific quality arising from the receptors in the digestive organs is scarcely observed; the general hedonic quality of comfort (pleasantness) predominates.

This predominence of the general hedonic quality over the specific qualities of the components increases as the number of constituent elements becomes greater. We localize a pin-prick quite definitely, and the pricking quality is fairly distinct. But if a great number of receptors are affected the localization becomes more vague and the specific quality grows indistinct. One is not always certain whether a certain pain is merely toothache, or toothache and earache combined. It is localized now in one part of the head, now in another. The same is true of digestive pains. In general, the more pervasive the feeling, the less clear and distinct are its specific component qualities and the more dominant the general hedonic quality.

Systemic components usually enter into our perceptions. For this reason some writers regard hedonic tone as a character or attribute of sensation, ranking it along with quality and intensity. From this point of view feeling is not a sensation, but a factor in the make-up of sensations.

If we observe our own experiences derived from the external senses we do find an hedonic quality attaching to many of them. The pleasantness of an harmonious chord and the unpleasantness of a noxious odor are elements in these perceptions. It is doubtful, however, whether the hedonic tone is a character of external sensations. It is more probably an added component, like the taste of the uncut orange. This

is supported by the fact that we learn to 'like' certain odors which were once unpleasant and to 'dislike' tones or colors which were formerly pleasing. On the other hand the general hedonic tone of organic and pain experiences is closely bound up with the specific stimuli of these senses. It changes only as these stimuli alter or as other systemic stimuli occur to modify the general central effect.

The physiological processes and the data observed in subjective experience seem best explained if we regard both the specific organic and pain qualities and the hedonic tone as due to interoceptive activity. The feeling tone which accompanies sight, hearing, etc., is due to a simultaneous stimulation of some internal receptors. Close observation indicates that organic sensations accompany the perception in all such cases. Extreme instances of this are the "ebullition of feeling" attending a full rich chord in music or the nausea aroused by a rank odor.

Characters of Feeling. — The characters or attributes which appear in perceptions are found also in feelings. *Quality* and *intensity* are the most important characters of feeling states. *Duration* varies with the duration of the stimulus. The *extensity* character is vague and indefinite. We distinguish between a pervasive pain or organic feeling, and a localized feeling; but the localization and extent of a pervasive feeling are not clearly defined — feelings derived from a group of receptors are not definitely related in a spatial manner to other feelings or to our perceptions. The grouping process is accompanied by a certain amount of focalization, which introduces the character of *vividness*.

The *qualities* of feeling, as already stated, include two independent variables, a general hedonic quality, or feeling-tone, and a specific quality which depends upon the nature of the stimulus and receptor. Of these, the hedonic tone is more prominent. There are two qualities of hedonic tone: pleasantness and unpleasantness.

Certain writers have claimed that other hedonic qualities exist. Thus Wundt finds three pairs of opposite qualities: pleasantness and unpleasantness, excitement and quiescence, strain and relief. Strain and relief are probably due to kinesthetic components which accompany certain feelings. Excitement and quiescence are due in part to the intensity factor and partly to kinesthetic stimuli; they characterize emotional states rather than feelings.

The *intensity* of pure feeling states is difficult to measure. Some attempts have been made, however, to measure the intensity of the hedonic tone of perceptual states. When the intensity of an external stimulus is increased continuously the intensity of the accompanying feeling varies also. But the change does not follow Weber's Law. We are dealing with a phenomenon which has two opposite phases, pleasantness and unpleasantness.

The general relations between intensity of external stimulation and hedonic intensity may be stated as follows:

(1) With a minimal intensity of stimulation the hedonic accompaniment is zero.

(2) As the intensity of the stimulus increases there is at first a slight degree of pleasantness.

(3) With further increase in intensity of stimulation the pleasantness increases to a maximum and then decreases.

(4) At a certain point the pleasantness disappears entirely.

(5) With further increase in intensity of stimulation unpleasantness appears and from this point on increases steadily.

(6) With great intensity of stimulation a maximum degree of unpleasantness occurs; this marks the beginning of actual destruction of some of the tissues. [Fig. 68.]

Focalization occurs in the formation of feelings, though not so effectively as in perception. This central process furnishes the character of *vividness.* Many separate systemic sensations may be stimulated at the same time. Where all bear the same hedonic tone, they sum up into one general feel-

ing experience, pleasant or unpleasant. Where they differ in tone, one feeling or group of feelings is focalized and the rest become marginal. An illustration of the combination effect is observed when a pleasant day, good news, and a well-ordered digestion combine to make us thrill with the

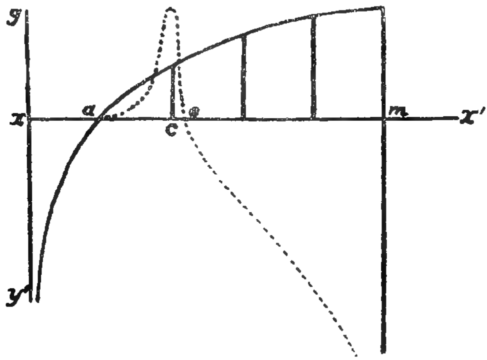

FIG. 68. — HEDONIC CURVE

Dotted curve shows change in degree of pleasantness (above x axis) and unpleasantness (below x axis) with increase of stimulus (left to right along x axis). The corresponding changes in intensity of pressure sensation are shown by the unbroken curve. [From Pillsbury, after Wundt.]

joy of living. The conflict is illustrated by the feeling of a wounded soldier who is oblivious to intense pain in the exultation of victory.

In general our mental life at any moment is characterized by a pervasive feeling state of some sort. Specific external experiences or ideas modify this general feeling tone from time to time, but we rarely find in the focus of conscious experience two conflicting feelings. Some writers in fact have declared that pleasantness and unpleasantness cannot be experienced together at the same time. This is one of those dogmatic generalizations which the scientist usually finds reason to challenge.

Under exceptional conditions it is certainly possible to experience two conflicting feelings. We experience pleasure when a friend sympathizes with us on the agony of an excruciating toothache; but this does not altogether obliterate the discomfort of the ache. At such times we experience both the unpleasant and the pleasant simultaneously, and it may be with equal vividness.

Appetite and Aversion; Excitement. — The consolidation of systemic sensations into states of feeling is far less developed in man than the consolidation of external sensations into perceptions or of ideas into imagery. There are several reasons for this. The systemic sensations are not qualitatively differentiated to the same extent as sight, hearing, touch, or smell. They are produced (except in the case of pain) by internal stimuli which are constantly changing. They are less closely connected with environmental conditions, which are of supreme importance in the life of the organism.

In civilized man systemic sensations are more frequently experienced as components of perceptions, imagery, and other states, than as independent states of feeling. At times, however, the intensity of the organic or pain stimuli is so great that the mental state is predominantly one of feeling, with the other components subordinate. These definite states of feeling may be divided into two classes, *appetites* and *aversions*, according as the dominant hedonic quality is pleasant or unpleasant.

Feelings of appetite result most frequently from digestive and sex sensations, while feelings of aversion are due to pain sensations and sensations arising from disturbed digestive conditions. In many cases the hedonic tone of a feeling is not pure. The feeling of digestive appetite, for instance, includes hunger components whose tone is unpleasant. A pain may be accompanied by pleasant sensations due to the healing process. At times the hedonic tone is indefinite, as

in cases of *excitement*. Intense feelings of any sort are apt to be accompanied by very intense kinesthetic components and are thereby transformed into emotions.[1]

Rôle of Feeling in Mental Life. — The importance of feeling in mental life is apt to be overlooked, owing to the emphasis usually laid upon perception and imagery. The external senses and their imagery give information concerning the world about us. In the same way the systemic senses give us indications of our own physiological condition. These data are consolidated into feelings.

The influence of feeling in determining our attitude toward the outer world may be observed by comparing the responses of different individuals under similar conditions; or better still by observing how differently the same individual acts in two cases where the external situation is similar but his own internal condition is radically different.

Some men apparently can never be disheartened or insulted; others will collapse at the slightest misfortune, or bristle at the most trivial remark. The external stimuli are alike; the difference lies in their systemic condition. The same man who meets difficulties energetically and cheerfully when in good health, may sit despondent and refuse to face danger or perplexity when affected by indigestion, malaria, or other weakening influences.

The real significance of feeling in our mental life can only be understood through a study of its biological history. Destruction of tissue is harmful to any creature. Hence, any creature which develops a means of avoiding such destruction will stand a better chance of surviving. Those creatures which are able (1) to avoid noxious stimuli and (2) to react positively to beneficial stimuli are more likely to survive in the long run. The mechanism for each of these two opposite types of response is developed through one of the phases of feeling.

[1] See ch. xiv.

The external receptors are not harmed except by very intense stimuli: hence, the pain nerves furnish an adequate means for discriminating harmful external stimuli from those which are beneficial or neutral. The internal organs require more delicate indications. They are more liable to disorganization through fatigue, poison, and other detrimental influences. But they do not ordinarily require a fine discrimination of qualitative influences. Hence, instead of building up complex 'perceptual' relations and qualitative distinctions like the external senses, the organic senses have developed central connections whereby their data tend to fuse into mass experiences — they furnish us indications of general pleasantness or comfort and of general unpleasantness or discomfort.

Mental life is above all concerned with the interaction between the organism and its environment. Accordingly, the most important development of the feeling experience is found in its combination with kinesthetic experiences to form emotions, which generally involve reaction upon the outer world.

4. Conations (Expressive States)

Nature of Conative States. — Every nerve impulse tends to discharge sooner or later into a motor nerve path. This motor discharge either produces muscular contraction; or it excites activity of the glands, which results in secretion. In either case the first effect of the motor discharge is to produce some motor activity which may serve as stimulus to a new sensory impulse. The resulting sensation 'reports' the result of the motor discharge.

In the case of glandular activity the report is indirect. So far as we know the glands are not provided with special receptors; but the secretory activity may stimulate some of the external or internal receptors. A tragic story may start a motor impulse to the tear glands, resulting in the shedding

of tears. Even apart from muscular accompaniments (such as sobbing), the flow of tears on the eyeball or down the cheeks serves as a stimulus to sight and touch. In the same way the sight of a juicy peach starts a motor impulse to the salivary glands; the mouth ' waters ' and this moisture serves to arouse sensations of taste and touch.

When the motor impulse affects the muscles the sensory effect is more direct. Muscular contraction and the resulting bodily movements are reported at once by stimulation of receptors situated in the muscles themselves. These stimuli and sensory impulses result in kinesthetic sensations (ch. x). Kinesthetic sensations combine together in the same way as external sensations or systemic sensations. Mental states in which kinesthetic components predominate are called *expressive states* or *motor consciousness;* a convenient term is *conation.*

Until recently it was supposed that we are directly aware of the outgoing motor impulse. Many observations and experiments, however, have shown quite conclusively that motor experiences are due wholly to sensory processes stimulated by the muscles, tendons, and joints as they move or are maintained in a fixed position. Conation, or motor consciousness, is our experience of the condition of our muscles and other motor organs or of the changes which they undergo in actual movement. It is a report from the organs to the center, not an experience of sending out motor impulses from the center.

Conation and Volition. — In examining behavior from the standpoint of the outside observer (ch. vi, vii), we distinguished between two types of complex behavior: instinct and intelligence. The mechanism for instinctive behavior is inherited. The structure used in intelligent behavior is largely inherited also, but the central connections are manifold, and individual experience determines which one of several possible paths is actually joined up in any instance.

When we observe our own motor experiences the dividing line is somewhat different. Instinctive acts and habitual intelligent acts are performed without hesitation. Sensations of various sorts find immediate expression and are followed at once by conative mental states. In neural terms this means that the sensory impulses are integrated and pass over without delay into motor paths, causing coördinated movements, which immediately stimulate kinesthetic (and sometimes static) sensory impulses. This type of activity is usually called *sensorimotor.*

Distinguished from this ‘ automatic ’ activity we find another type of intelligent behavior in which the motor discharge is delayed while new connections are formed at the centers. Sensations are followed by ideas and the motor discharge does not occur till later. In these experiences, images or thoughts are interpolated between the original sensations and the conative states. In neural terms this means that a longer central arc is involved, and that the central impulse is modified by the retention traces in these interpolated central neurons. This type is called *ideomotor* activity.

A mental state which occurs as the result of *sensorimotor* activity is a simple motor experience or *conation.* We may define conation as the mental state which accompanies any ‘ involuntary ’ or ‘ automatic ’ movement or any bodily position of which we are aware. When we dodge to avoid being hit, or when we adjust our steps in walking, our experience of the action is a conation.[1]

In *ideomotor* activity the mental state includes not only kinesthetic sensations, but also an image of some sort which pictures the performance of the movement. This type of

[1] If the motor activity is entirely unobserved, as happens in certain cases of extreme inattention, it is scarcely proper to class it as ‘mental state’ at all. We find ourselves at a certain gate without any recollection of our movements in getting there. These extreme automatic movements may be experienced in some detached system of arcs, but of this there is no certainty.

mental state is called *volition.* Volition involves two kinds of components, external ideas and motor sensations.[1]

Composition of Conative States. — Our conative mental states are combinations of various elementary data in which kinesthetic and static sensations predominate; they include also elementary kinesthetic ideas and certain data from sight, touch, etc., which indicate the position and movements of our body or some of its members. By discriminative observation we can distinguish sensations of pull, strain, force, energy, effort. When the movement is checked by some obstacle or impeded by an opposing force we have a sensation of expended energy, or resistance.

This 'dynamic sensation' is the specific quality of conative states. It does not imply actual performance of movement or ability to perform it. If a muscle has been injured or the nerve leading to it is severed we may nevertheless experience the sensation of power or energy. Where a muscle and its motor pathway are unimpaired but we have not learned to connect them up, we may still experience the sensation of effort. In such cases careful observation shows that the sensation is due to slight motor stimuli in the neighborhood of the muscles in question. Although we do not actually contract the ear muscles, we do send motor impulses to other muscles in the same general region; in the case of injured muscles or severed nerves the kinesthetic sensations are real, but they come from neighboring muscles.

The imagery factors included in conative states are mainly reproductions of external sensations. We recall the position of our arm, head, or other member as seen or 'palped.' Muscle-sense imagery is vague and enters into the experience but slightly: the kinesthetic image tends to produce an actual movement, so that usually actual kinesthetic sensations predominate over the corresponding imagery.

Hedonic elements, especially pain, enter prominently into

[1] Mental states with a two-fold basis will be treated in the next two chapters.

some conative states. These feeling components often initiate secondary motor impulses which tend to inhibit certain movements and reinforce others. The perception of a flame may lead to a withdrawing movement and the perception of a luscious peach may bring about a grasping movement. The motor impulse is initiated in one case by the unpleasantness, in the other by the pleasantness of earlier experiences.

Conations or simple motor states of consciousness, then, consist essentially of kinesthetic and static sensations, to which are added auxiliary elements from the external senses, together with memories and hedonic elements. Conation is generally not so vivid as perception, but it constitutes a well-organized experience; this organization shows itself in the fine motor adjustments which take place in sensorimotor activity.

Varieties and Rôle of Conation. — Conative states are classified according to the type of behavior which they accompany. Human conations include the following classes:

Reflex conations
Instinctive conations
Tendential conations
Habit conations

Reflex conations occur when a reflex action generates a kinesthetic stimulus, whose impulse reaches the higher centers. When we start at a sudden noise the movement resulting from the reflex arouses a conative mental state. Coughing and sneezing are accompanied by conation. If we test the various reflexes listed in Table III (p. 101), we find that in nearly all cases the activity is accompanied or immediately followed by motor sensations which are grouped together into an integrated mental state — a motor experience or conation. In some reflexes the secondary motor sensations[1] are most prominent; — in winking we experience especially the visual change, in sobbing and laughing the auditory sensation. In other reflexes the kinesthesis is subordinated

[1] See p. 210.

to perception or feeling; iris and accommodation sensations enter into perceptual states and lose their identity; they make for 'clearer vision.'

Instinctive conations most frequently accompany instincts classed as *nutritive* (Table IV), such as wandering, acquiring, cleanliness. In mental states which accompany other types of instinct the systemic components are apt to be more vivid; in fighting, sympathizing, mating, and even in modesty reactions, the mental state is an emotion.

The states which characterize instinctive tendencies are sometimes emotional, sometimes volitional, but in many cases they are dominantly conative in type. These states may be called *tendential conations.* There are many instances of sensorimotor curiosity in which the mental state is almost wholly conative, with only marginal elements of feeling or imagery.

Imitation, when it occurs spontaneously, is a typical conative experience. It depends upon inherited mechanisms which connect external receptors with motor paths leading to muscles in the appropriate regions. When we see another person perform a certain movement with his hands, the motor paths to our own hand muscles may receive an impulse; when we hear a succession of musical sounds the motor paths to our vocal muscles are likely to be excited. The mental state in such cases is a conation.

Conative mental states accompany intelligent acts when these proceed without delay and without the intercalation of higher central neurons in the arc. Our fixed habits belong to this class. The mental states which accompany them may be called *habit conations.* When one signs his own name the mental state which accompanies the neural response in most cases is essentially conative. Singing, piano-playing, recitation, typewriting — all such learned acts may be nonvoluntary, and the corresponding experiences are conative.

At times such acts are performed with only marginal con-

sciousness, but usually some focalization is essential. If the focus of consciousness is elsewhere the act miscarries, and we make some absurd blunder. We tear up the letter instead of the envelope; or we summon the maid and when she comes we have no idea what we wanted. Fixed habits in general are sensorimotor (not ideomotor) and are centrally characterized by conation.

Conative mental states do not occur so frequently in the aggregate as the other primary states. Vivid imagery or vivid feeling usually accompanies the kinesthetic elements, so that the resulting experience contains two kinds of components and becomes a secondary state; it is a *volition* if the ideational factor is prominent, an *emotion* if the systemic factor is strong. In human mental life conation generally rises into voluntary activity. In subhuman species the more prevalent type is emotion.

Collateral Reading:

Titchener, E. B., Text-Book of Psychology, secs. 68–74, 112–126.
James, W., Psychology, chs. 18, 19, 23; Principles of Psychology, ch. 18.
Angell, J. R., Psychology, chs. 8, 9, 13, 14.
Külpe, O., Outline of Psychology (trans.), Part I, sec. 2.
Pillsbury, W. B., Fundamentals of Psychology, chs. 6, 10, 13.
Breese, B. B., Psychology, chs. 10, 11, 16.
Judd, C. H., Psychology, General Introduction (2d ed.), chs, 9, 11.
Royce, J., Outlines of Psychology, ch. 7.
Galton, F., Inquiries into Human Faculty, ch. on Mental Imagery.
Hering, E., Memory (trans.).
Washburn, M. F., Movement and Mental Imagery, chs. 1–5.
Peillaube, E., Les images, Part I.
Titchener, E. B., Psychology of Feeling and Attention, chs. 2–4.
Münsterberg, H., Die Willenshandlung.

Practical Exercises:

Read a chapter from some history or novel, and note the images which are aroused; classify them according to image-type and sense-type.

Lying in bed at night with closed eyes, try to picture imaginary scenes or stories. Describe the experiences; compare their vividness with real scenes; how far are they due to retinal stimulation?

Analyze your general state of feeling at three different times; e.g., on waking, after a hearty meal, after a brisk walk.

Analyze the experience of catching a ball.

CHAPTER XIV

SECONDARY MENTAL STATES

Nature and Classification of Secondary States. — In the two preceding chapters we have examined the mental states which are homogeneous — whose chief components all belong to the same general class. There are in addition certain kinds of mental states into which two or more varieties of data enter. Thus emotion is a mental state which combines systemic and motor elements. An emotional state is usually aroused by some external stimulus or by some ideational state, but in the emotional experience itself the perceptual or imagery components are subordinate elements. For example, an emotional state akin to our experience of anger is aroused in a bull when he sees a red cloth; the red perception is the basis of the emotion, but the emotional state is systemic and kinesthetic. In man, the emotion of love may be aroused by the sight of a fellow-being or the sound of a well-modulated voice; but the emotion itself is a combination of feeling and conation. For want of a better term these heterogeneous mental states will be called *secondary,* though some of them may have originated prior to primary states, and they are frequently less complex than the latter.

Data from the external senses (perceptual elements) are rarely if ever among the prominent constituents of secondary states. External stimuli are so intense and obtrusive that the resulting impulses either reduce the other constituents to a subordinate rôle or else they themselves become subordinate through focalization of the other elements. In anger the systemic and motor sensations, once aroused, tend to become exceedingly vivid, and the perception which aroused them becomes marginal. But if we focus the perception — if we attend to the external situation — the emotional state

fades into the background, and we cease to be angry. In secondary states ideational elements take the place of exteroceptive data.

There are well-defined classes of secondary states for each pair of components, excluding external sensations; and there are states into which all three sorts of components enter as focal constituents. The classes of secondary states are shown in Table XV. It will be noticed that in certain cases there is more than one line of development. *Volition, thought,* and *language* are various types in which ideational and kinesthetic components are dominant. Language differs from volition in the prominent part which the social factor plays in its development.

TABLE XV. — SECONDARY MENTAL STATES

Mental States	*Dominating Components*
Emotions	Systemic and Motor Sensations
Sentiments	Ideas and Systemic Sensations
Volitions	Ideas and Motor Sensations
Thought and Language (Social)	Ideas and Motor Sensations
Ideals and Rational Actions (Social)	Ideas; Systemic and Motor Sensations

1. EMOTIONS

Nature of Emotion. — An emotional state is a combination of systemic and motor elements. It is characterized by a vivid feeling tone, either pleasantness or unpleasantness; and a specific systemic quality is usually prominent, due to the condition of certain internal organs, or to the mode of the pain stimuli if these are concerned. In emotion there is also great muscular activity or a condition of high muscular tension. These kinesthetic stimuli excite motor sensations, which are always a prominent factor in the emotional experience.

Emotion is the earliest secondary state to arise in the animal series. The fundamental emotions of fear, anger, and love appear well down in the biological scale. It should

be noted too that emotion is the only secondary state in which ideational elements do not play a prominent part. The experience is aroused by external stimuli or ideational impulses, but in the emotional state itself these components are unimportant. Emotion is concerned far more with our bodily organization and with action upon the environment than with perceptions or ideas of the outer world.

According to the older psychology, feeling constitutes the chief factor in emotion: the systemic sensations were supposed to occur before the kinesthetic and to furnish the stimulus for the motor phenomena. This interpretation assumes that we first experience the *feeling* of anger, then clench our teeth and fists, scowl, and assume the general anger *attitude*. William James and Carl Lange independently suggested that the factors really arise in the opposite order: We first of all assume the anger *attitude* — clench our teeth and fists, and strain the tension of our muscles; these movements stimulate in turn the anger *feeling*. That is, according to these writers, *the motor components generate the feeling components of the experience.*

Some confirmation of this theory is found in the fact that if we artificially assume the anger attitude with all its kinesthetic accompaniments, the feeling elements are thereby aroused to a noticeable degree; on the other hand in natural anger, if we succeed in relaxing the muscles and thus rid ourselves of the kinesthetic elements, the feeling of anger diminishes and the entire emotion tends to vanish.

On the whole, however, the facts seem to indicate that the systemic and kinesthetic factors are coördinate; both are aroused by some perceptual or ideational experience — both arise simultaneously. If we succeed in relaxing the muscles, the emotion vanishes — it passes over into a simple state of feeling. If we succeed in removing the systemic components the experience reduces to mere conation. Most persons are able to control their motor expressions more readily than their

systemic processes. Hence, when we make an experimental test the kinesthetic factor seems to be the crucial factor. In point of fact, emotion is the joint product of systemic and kinesthetic impulses.

Primitive Types of Emotion. — Emotion is the most primitive of all the secondary mental states. We gain considerable insight into its nature by studying its manifestations in various animal species. But this study has consisted too frequently in reading human emotions into animals, just as popular psychology is apt to read too much of human thought and reasoning into subhuman types of behavior.

A better insight is gained by reading animal experiences into man. When a cat marches majestically away from a growling dog with an air of offended dignity, we are naturally inclined to read into her experience the ideas and thoughts which cause the corresponding display in man. But it is more profitable psychology if we realize that the inciting stimulus in the animal is purely perceptual. From the similarity of the behavior manifestation in the two cases we may reasonably infer that even in man the pride emotion is due more to perception and less to ideas than is generally supposed.

The analogy should not be pressed too far. In point of fact human emotion differs from animal emotion chiefly in the prominent part played by imagery and other ideational experiences in its production. Few of our emotions in adult life are purely perceptual, like the anger of the bull at the sight of red. A child cries when we pinch a rubber stopper, or manifests fear at the sight of a snake or some other strange creature. In the adult, emotions are determined by ideas rather than perceptions. We are angry when we see a big boy beating a small boy; we are not angry when we see a strong man beat a rug.

The most primitive emotions in man are those whose bases are found in long inherited structure. and which may

be traced far down in the animal scale. The three most fundamental types are *anger*, *fear*, and *love*.

The hedonic tone of *fear* is unpleasantness, which is usually present in a high degree of intensity. The specific organic sensations which occur in fear are stimulated through receptors in the lower viscera and in the region of the lungs and heart. The characteristic motor phenomena of fear are certain definite muscular contractions, which produce trembling, shrinking movements, raising of the eyebrows, etc. These motor activities furnish kinesthetic sensations which enter prominently into the emotional experience.

In *anger* the general hedonic tone is characteristically unpleasant, but it is not so prominent as in fear. The specific systemic sensations are connected with the upper digestive tract, the heart and lungs, and the circulatory system generally. An outburst of anger is accompanied by vigorous heart activity and breathing, which usually causes intense flushing of the face and sometimes a choking sensation and suffusion of the eyes. The characteristic motor activities are clenching of the fists and teeth, strained tension of the facial muscles, and rigidity of the lower limbs. These motor activities are accompanied by very intense kinesthetic sensations. The expression of anger is generally movement *toward* the object — in fear the movement is *away from* its object.

Love is the third type of primitive emotion. Its characteristic feeling tone is pleasantness. The specific systemic qualities are less prominent than in fear or anger; they arise from the region of the lungs and from the sexual organs. The popular notion which associates the emotion of love with the heart is not so far wrong: careful observation shows that the sensation is located somewhat *above* the heart, but that it is due to the circulation and not to breathing. There are various motor accompaniments of this emotion, and the kinesthetic sensations which these excite enter prominently into the experience. A somewhat less intensive variety of

the emotion is found in *sympathy*. Here the hedonic tone (pleasantness) is predominant, and the specific qualities are less definite than in love. The motor tendencies in sympathy are generally ' movement toward ' the object, and are often accompanied by activity of the tear glands.

Classification of Human Emotions. — The emotions observed in man have been classified in various ways according as one characteristic or another is the fundamental criterion. They may be grouped according to their temporal reference (present, past, or future), their object (emotions regarding ourselves, our fellow men, animals, and inanimate objects), hedonic tone (pleasant or unpleasant), or rate of increase (abrupt or gradual rise). All these conditions are important factors, but they do not indicate the relative importance of the several kinds of emotions. Some types of emotion have developed tremendously; others which parallel them are quite trivial. A purely logical scheme fails to bring this out. We can only determine by actual observation and experiment just what emotions actually play an important rôle in life.

Since the emotional life dates far back in organic history, we can utilize subhuman material to a greater extent than in other mental states. But this applies only to emotions which refer to the present: retrospective and prospective emotions are founded on vivid memories or vivid anticipation images which do not occur in subhuman species. An important aid in the study of emotions is the names of emotional states found in the languages of civilized and uncivilized races. Experiences which reach further back in race history are likely to be named first and to have a greater variety of differential names than those recently acquired.

W. McDougall has pointed out that many emotions correspond more or less exactly to types of instinctive behavior. But human instincts, as we found in chapter vi, have become modified in various ways by intelligence; certain emo-

tions have been inhibited or strengthened so that the parallel with instinct is obscure. In some cases two or more types of emotion correspond to the same instinct. A list of the more important human emotions with their instinctive bases is given in Table XVI.

TABLE XVI. — HUMAN EMOTIONS

1. *Expressive (Nutritive)*

Emotion	*Basis*
+ Joy (Enthusiasm)	Diffused feeling
− Grief (Despair)	"
− Shock	"
+ Mirth	"
+ Ecstasy	"
Restiveness	"
Exuberance	Play
+ Wonder	Curiosity

2. *Reproductive*

Emotion	*Instinct*
+ Love	Mating
+ Lust	"
− Jealousy	"
− Coyness	" (female)
+ Tenderness	Maternal

3. *Defensive*

Emotion	*Instinct*
− Fear	Flight and Hiding
− Disgust	Avoiding
− Timidity (Embarrassment)	Shyness
− Shame	Covering
+ Awe	Subjection

4. *Aggressive*

Emotion	*Instinct*
− Anger (Passion)	Fighting
− Hatred	Resenting
− Envy	Rivalry
+ Pride	Domineering
+ Exultation	"

5. *Social*

Emotion	*Instinct*
+ Affection	Family
+ Cordiality	Gregarious
− Pity	Sympathetic
+ Gratitude	"
+ Admiration	"
− Detestation	Antipathetic
− Revenge	"
− Suspicion	"
− Scorn	"

6. *With Temporal Projection*

Retrospective Reference:
- − Regret (Remorse)
- + Satisfaction (Elation)
- Surprise

Prospective Reference:
- + Hope
- − Dread
- Anxiety

There appear to be no specific emotions directly attached to the nutritive instincts. There are, however, a number of

'expressive' emotions, such as *joy* and *grief*, which are probably indirectly due to the nutritive functions. On the other hand the expressive emotions of *exuberance* and *wonder* are not traceable to the nutritive functions at all, but to the instinctive tendencies of play and curiosity. There appears to be a fairly close correspondence between the remaining types of instinct (reproductive, defensive, etc.) and well-marked types of emotional experience. Certain additional emotions are differentiated on the basis of their temporal projection. The prospective emotion of *hope*, and the retrospective emotion of *satisfaction* are similar to *joy* apart from the temporal coefficient. These types make up a sixth class, which has apparently no instinctive basis.

In many cases we may readily note a number of different shades of emotion which belong to the same general type. Some of these varieties are of considerable importance in mental life and have received distinctive names. *Remorse*, for example, plays quite a different rôle in mental life from *regret*. Only the most prominent variations are given in the Table.

The hedonic tone of the emotions is indicated in the Table by + where the tone is pleasant, and by − where it is characteristically unpleasant. The emotions of uncertainty (restiveness, surprise, anxiety) may be characterized by either tone; frequently the tone alternates between one quality and the other.[1]

Rôle of Emotion in Mental Life. — The emotions, more than any other kind of mental states, represent by-gone conditions of life. Many of them may be regarded as fossil remains of our prehuman ancestors. They do not fit particularly well into the human world of to-day. This is apparent in the efforts which the community makes, through tradition and schooling and family training, to suppress or

[1] For treatment of the motor manifestations of emotion see references at end of this chapter, especially Cannon and Crile.

modify their manifestation. These attempts to reduce our emotional life to a minimum are not always well advised. Suppression is not necessarily eradication. Freud has shown that the effort to repress often results in nervous disorganization. On the moral side it fosters deceit and hypocrisy.

The objection to the contemporary attitude toward emotion is that it is not founded upon psychological analysis. If we study the emotions separately we find that they differ considerably in value. Some are distinctly harmful to the individual in his relations to the environment — especially the social environment. But others are quite as truly beneficial, while others may be classed as neutral.

There is no doubt that the defensive emotions refer back to prehistoric modes of defense, and that for the most part they hamper us under modern conditions. This is even more true of aggressive emotions. On the other hand the social emotions harmonize well with modern social conditions, except those based upon the antipathetic instincts. The reproductive emotions require training to fit them into the social life of to-day; but in some communities this training has gone to extreme lengths. The reproductive instincts are fundamental to life; we may tone down their primitive modes of expression, but in suitable form they are a requisite part of the individual's mental life.

In general, the expressive emotions and the corresponding retrospective and prospective types may be classed as neutral from the social standpoint. In their extreme manifestations they do not fit in with modern life. But a moderate display of joy, grief, mirth, regret, hope, and the like is not socially detrimental and is of some benefit to the vital life of the individual.

What has just been said is not intended as a lesson in pedagogy, though it might well be taken into account in our program of self-training. It is merely to point out that the emotional part of our mental life is to some extent an an-

achronism. Emotion, if uncontrolled, hampers the proper interrelation between the individual of to-day and the environment of to-day. It is only when the instinctive emotions are trained into intelligent modes of expression that this phase of mental life works harmoniously with the rest.

2. Sentiments

Nature and Classes of Sentiment. — A sentiment is a mental state whose leading components are feelings and imagery. It is due to the combination of systemic with ideational impulses.[1]

Sentiments may be aroused by any sensory or ideational impulse, but the state aroused is essentially different from a perception or an image. A typical example is our "sense of beauty," which is not a sensation nor a perception, but a sentiment. The experience may be brought about by seeing the Venus de Milo or by listening to Beethoven's Fifth Symphony; or the memory of one of these may arouse the same experience. The sentiment of beauty, however, is distinct from the perception or other state which arouses it. The perception *suggests* the sentiment; a radical *transformation* of the mental states takes place, and the sensory and other components of the antecedent state drop out or become subordinated. The focal components of a sentiment include elements of two sorts: an *idea of value* [2] and a *feeling*.

Sentiments are classed according to the type of primary experience which arouses them. The principal varieties of sentiment and the states which suggest them are shown in Table XVII.

[1] The term *sentiment* has a somewhat technical meaning in psychology. It is not precisely what we mean by 'a sentiment' in ordinary language, nor does it correspond to the adjective 'sentimental'; but it carries a trace of each notion — the imagery of the former and the feeling tone of the latter.

[2] For the discussion of *value*, see ch. xv.

TABLE XVII. CLASSIFICATION OF SENTIMENTS

Sentiments	*Source*
Reality Feelings	Perceptions
Beliefs	Ideational States
Esthetic Sentiments	Systemic States
Dynamic Sentiments	Motor States
Moral Sentiments	Social Situations

In general, when a sentiment has once been aroused it persists, though less vividly, and attaches to the mental state which excited it, so that we " read the sentiment into " the objective situation: we characterize the object or event as *real, true, beautiful, powerful,* or *good.*[1] This association of the sentiment with the state which arouses it has led to much futile discussion as to whether an act is ' good ' in itself, whether a painting is ' beautiful ' when not observed, etc. There seems no doubt that sentiments are due to something specific in the inciting objects or acts; so that the latter may properly be called moral, esthetic, etc., as the case may be. But in many instances the same object or act arouses a different quality of sentiment in different individuals. It seems doubtful therefore whether we should read the sentiment into the situation which induces it without some reservation. Royce very properly distinguishes between the world of *fact* and the world of *appreciation.* The sentiments belong to the latter sphere of experience.

Types of Sentiment. — The sentiment of realness, or *reality feeling,* attaches to perceptions of the outer world. We are ' sure ' that the objects which we see, palp, heft, hear, etc., really exist. In ordinary perception this experience is marginal. Like the familiarity feeling, it appears only as a subordinate element in the perceptual state. In adult life the reality feeling rarely occurs as an independent experience.

[1] It is interesting to notice how frequently these adjectives or their equivalents are used for mere emphasis, without reference to the origin, in such phrases as "a real fine day," "a pretty accurate description," "a mighty well-written story," "a right satisfactory outcome."

Occasionally it becomes a focal state when something which we see, hear, etc., is unlooked for and does not fit in with our general scheme of experience. If we meet a friend whom we thought a thousand miles away, the reality feeling bursts through into prominence. On the other hand in day-dreaming, or when we are dazed by a sudden blow or a loud noise, the reality coefficient is often quite lacking — things about us do not impress us as real. In certain pathological conditions the sense of reality disappears entirely: the patient declares that nothing around him seems to be really existent.

Belief is similar to reality feeling. The perceptual components are replaced by ideational elements. We are 'sure' that certain of our images and thoughts are true. Owing to our ability to picture and represent things which are not true, two varieties of belief have developed. We may either believe in the existence of the object thought of, or we may believe that such an object does not exist. We may believe in the truth of a generalization or in its falsity. When one pictures a mermaid, the sentiment attaching to the image is a belief in its falsity, while if we picture Vesuvius the sentiment takes the form of belief in the truth of the representation. In these two cases the sentiment is of the same general nature (belief) but the tone of the two is different. The difference is not in the feeling, but in the *attitude* which we assume (ch. xvii). The appreciative attitude of 'not' gives a special tinge to *disbelief*. *Doubt* is another species of sentiment aroused by ideational states, and is the true opposite of belief. Doubt arises from alternation of the two varieties of belief: truth sentiment and falsity sentiment.

Esthetic sentiments arise indirectly from perceptions. In certain perceptions the feeling tone is especially prominent, and this systemic element combines with an idea of harmony or value. This combination of feeling and idea at times becomes focal, and is experienced as an independent mental state. Esthetic experiences include sentiments of

beauty or harmony, and ugliness or discord. The two opposite varieties are distinguished by the nature of the feeling tone — in one case pleasantness, in the other unpleasantness. The intensity of the esthetic sentiments varies greatly with the individual and with training. In some individuals the appreciation of beauty, harmony, etc., appears early in life and develops without any special training; in others it is attained gradually, through education and imitation. The prevalence of esthetic sentiment is characteristic of the 'artistic' type of personality.

Dynamic sentiments have been less carefully studied than the other types. They arise when the kinesthetic elements in perception become unusually prominent. When an intense feeling tone is joined to an idea of power the result is a dynamic sentiment. The kinesthetic sensations, it will be recalled, are stimulated by the activity of our own muscles; but their intensity varies with resistance to movement, which is due to forces in the environment. These two factors, the internal and external, are represented in the qualities of dynamic sentiments. Where the internal stimulus is dominant the sentiment is one of *power*, or ability to act. Where the external resistance is strong, the sentiment is one of *opposition*, of *being thwarted*, of *force or power in the environment.* The extreme case gives rise to the sense of the *inevitable.* At times dynamic and esthetic sentiments combine into a mental state called the sentiment of the *sublime.*

Moral sentiments arise from the feelings which attach to our perceptions of social acts — usually those of other persons. Certain acts arouse approval, others arouse disapproval. This feeling is combined with the idea of social value and becomes a moral sentiment. There are two principal classes, the sentiment of *right* and the sentiment of *wrong.* Where the sentiment attaches to the whole conduct of any individual it is termed *good* or *bad.*

Rôle in Mental Life. — Sentiments figure as the least im-

portant type of mental states in the sum-total of our experiences. If a sentiment is weak it remains marginal and has little influence. If it is intense it tends at once to some motor discharge, which introduces the kinesthetic factor; in this case it ceases to be a sentiment and becomes an emotion or a volition or an ideal.

We do not usually rest with a mere sentiment of condemnation or approval. We are apt to start in, hand and fist, to remedy the wrongs which we condemn. We 'push along' a good deed, literally as well as figuratively. Moral sentiments pass over into action and become volitions or expressions of our ideals; esthetic sentiments, if they are strong, pass over into emotion; dynamic sentiments arouse activity as we strive to overcome resistance or to express our ability and assert our power.

In other words, sentiments lack stable equilibrium; if they are weak they are crowded out of focus by other states; if they are intense this very strength transforms them into other states. Beliefs are the most stable of all sentiments. They may persist through life, undergoing transformation and change of quality from time to time, but without losing their essential characteristics as sentiments.

3. Volitions

Nature of Volition. — Volition is a type of mental state in which conative and imagery elements are combined; it is due to the summation of kinesthetic stimuli and ideational impulses. In human beings perception frequently does not lead immediately to motor discharge. The central impulses which we observe as perceptions pass over into higher central neurons and produce imagery or other ideational states. The motor discharge, when at length it occurs, is *ideomotor*.[1]

In human mental life it frequently happens that the ideational state which immediately precedes the motor impulse

[1] See p. 288.

is an anticipation image — it represents some future movement. There is no structural reason why an anticipation image should issue in the appropriate movement. When we have an idea of moving our hand and grasping a book, the motor discharge might lead to various other sorts of action, so far as the inherited central connections are concerned. There is at most a broad *regional* connection between the sensory and motor centers. The centers for touch and motor discharge lie close together in the Rolandic region, and the specific center for touch in each part of the body lies opposite the motor center for the corresponding locality; but further than this there is apparently no structural correspondence. At the outset the idea of grasping a book might result in quite inappropriate muscular contractions and movements, such as withdrawing the arm or extending the fingers.

In the course of our early life, by trial and error, the 'inappropriate' responses are inhibited, and responses which correspond to the anticipation images are acquired. In other words, our actions come to be like our anticipation images through natural selection. When we picture raising the head, that very action follows; when we picture tracing the letter *m* with a pen on paper, our hand and fingers actually perform the movements which we have imaged.

The mental state which issues in these appropriate coördinated movements is not purely ideational. It is a combination of imagery with kinesthetic sensations. This type of secondary mental state is called *volition* or *will*.

In the older psychology volition was treated as an original datum of consciousness, or as a primary faculty of mind which initiates action independently of central nervous conditions. Experimental evidence goes to show, on the contrary, that it is a secondary mental state due to combination of two different sorts of data, that it arises through chance neural connections, and that its appropriateness is due to natural selection. A crucial experiment by J. H. Bair on learning to move the

ear may be cited. He found that no amount of intense effort or vivid picturing of the operation served to produce the actual movement. The idea led to various movements of adjoining parts of the scalp. Electric stimulation of the ear muscles assisted in giving the image definite location, but at first the only motor result was an ability to hold the muscle relaxed against the contracting stimulus of the electric current. Gradually the control was extended through action of adjacent muscles, till at length complete voluntary control of the muscle was obtained.[1] The process was found to consist in connecting up the motor paths to the appropriate muscle with habitual paths, and then gradually eliminating the latter from the circuit.

Regarded as a central or mental state, volition consists of (1) an anticipation image or thought of certain movements and of the changes produced by them in the environment, and (2) a conative experience of kinesthetic sensations involved in these movements and in certain bodily positions incident to the act. The ideational components are derived from external data, the kinesthetic sensations are derived mainly from muscular tension and incipient movements.

More than any of the mental states so far discussed, volition is concerned with the motor discharge and muscular contractions which follow. It is essentially *anticipatory.* It is the first mental state in which the emphasis is to be placed on the *action of the organism upon the environment;* in all the types so far treated the receptive side is most prominent.

Three phases of volition have proved fundamentally important in mental life: *voluntary activity, purpose,* and *voluntary control.*

Voluntary Activity. — Voluntary activity is characterized by *delay* and *choice.* The delay or latent period which distinguishes voluntary from sensorimotor and simple ideomotor activity is due partly to inhibitory impulses and partly to the

[1] *Psychol. Rev.*, 1901, 8, 474–510.

succession of central processes (ideas) which occur before the motor discharge takes place.

Inhibitory impulses are an important factor in voluntary activity. The idea of a movement tends to pass over immediately into motor activity; but in certain cases the tendency is checked by an inhibitory impulse. I start to go out walking, but the impulse[1] to open the door and go out is checked until other preparatory movements are made, such as putting on a hat or consulting memoranda. The latent period in which one idea succeeds another before action takes place is called *deliberation.*

The selective character of volition (*choice*) is due to the complexity of the neural conditions. When the tendency to immediate response is checked, the voluntary state is often followed by another idea and conation, representing some alternative activity, and so on through a long series of voluntary experiences. One of these at length becomes so strong that it leads to motor discharge and the result is an actual voluntary movement. When I get out of bed on a holiday morning my first 'plan' is to spend the day reading in the library. The bright spring weather suggests the alternative plan of motoring through the country. The pressure of daily duties suggests finishing a half-written article. Finally, the thought of a long brisk walk, combining pleasure with exercise, proves the most powerful impulse, and my voluntary activity proceeds along this line.

Volition is selective, not because it determines events which are otherwise 'indeterminate,' but in that it tends to bring about the *fittest* actions, rather than the *most obvious.* In any response the path of motor discharge is along the line

[1] In popular psychology *impulse* is used to denote a tendency to act based on internal motivation. The discussion in the preceding section indicates that this tendency is not 'innate' as is popularly supposed; accordingly this use of the term had best be avoided. In the illustration given here there is *both* a motor nerve impulse and an impulse in the popular sense of the term.

of least resistance, but in volition the central impulse undergoes a great variety of modifications before the path of discharge is opened up.

Voluntary activity is acquired and perfected by means of the learning process (ch. vii). Instances of voluntary learning may be observed in the formation of *general* habits, such as reading, writing, singing, violin or piano playing, typewriting, or the like, when we follow a deliberative plan instead of proceeding by active trial and error. A specific or *concrete* habit, such as learning a certain tune, may also be acquired by voluntary deliberative selection. As a voluntary habit becomes inground, its performance tends more and more to start without a preliminary period of deliberation and reviewing of the alternatives. A perfectly fixated habit is a pure conation.

Purposive Factor in Volition. — The ideational factor in volition is called a forethought, plan, or *purpose.* It is the image or thought of a prospective action. If the act or movement pictured is later carried to completion the forethought is followed by a perception similar to itself. The forethought is a present anticipation image founded on past experiences, to which a future reference or projection is attached.

Anticipation images or thoughts serve as bases for future actions on account of the uniformity of nature. Just so far as the circumstances are similar we may apply past experiences to future conditions; but if the circumstances are quite new, our forethoughts are usually quite vague. The thought of going to my laboratory leads at once to the appropriate movements of walking, turning, climbing, etc., because I have gone over the same path in the same way to the same place for many years. On the other hand when a young man is planning out his life career, the general situation and most of the circumstances are so different from anything in his past experience that his picture of the future is very indefinite; it is usually no more than a bare schematic outline.

The distinguishing mark between a purpose-idea and other anticipation images is the prominence of our own activity in the purpose experience. Purposes are essentially representations of our own actions. The ideas are not always kinesthetic — they may be visual or tactile; more often they are thoughts — mere verbal symbols rather than pictures of the act (ch. xv). When kinesthetic sensations of effort or energy are attached to the purpose-idea, it is transformed into a volition. But even apart from these kinesthetic accompaniments the purpose-idea itself has a reference to the individual's own doings which is lacking in anticipation images generally.

Some writers have claimed that volition contains another factor besides the purpose-idea and motor sensations. When voluntary activity is started the mental state is noticeably different from the preceding state of deliberation. This difference has been attributed to a specific mental element called the *fiat*. It seems more than probable, however, that the fiat is merely an intense kinesthetic condition which belongs to the dominant alternative — not a distinct component. We do not find it in habitual actions, which proceed without deliberation.[1]

Voluntary Control; Rôle of Volition. — Control is the physiological process of coördinating motor activity by means of central adjustment. We may distinguish four types of central control: *autonomic*, *instinctive*, *automatic*, and *voluntary*.[2]

Autonomic control is adjustment of the organic processes, such as digestion, through the sympathetic or autonomic system. In some cases both the sensory and motor paths of the arc are through neurons of the sympathetic; in every case the motor paths belong to this system. The cerebrospinal system may modify autonomic activity through impulses which cross to the sympathetic in the sensory and central segments.

[1] See Appendix, "Conscious Purpose," p. 427.

[2] A fifth and higher type, *rational control*, will be treated in ch. xv.

Instinctive control is adjustment through arcs of the cerebrospinal system which are definitely and permanently formed when the first impulse passes through them. As we noticed earlier (ch. vi), these arcs are not fully formed before they come into actual use. But the central terminals of their sensory and motor paths are so placed by structural inheritance that when an impulse passes over the neurons the connection is made, since it proves to be the path of least resistance.

Automatic control is sensorimotor or simple ideomotor adjustment which is not structurally determined, but has been built up by 'trial and error.' It occurs when the central terminals of the sensory and motor paths have many branches, no one of which furnishes at all times a path of least resistance. The circuit actually joined up has already been formed by accommodation and fixation, and the operation is accompanied by a conative mental state.

Voluntary control is complex ideomotor adjustment. Here the motor path is determined by a higher integration of impulses and by a succession of central states, among which are anticipatory ideas, or forethoughts, as well as kinesthetic states.

As already stated, anticipation and forethought bring the individual's past life, and to a certain extent his future, into intimate connection with the present. The prominent feature of voluntary control is that the action is determined by the man's *whole life*, not merely by present situations. Our voluntary acts are the expression of our *selves;* we control them as *personal beings* (ch. xviii). It should be remembered, however, that the precision of voluntary control varies according to our mental capacity, as determined by heredity and past experience. Any defect in the neural or terminal mechanisms, whether sensory, central, or motor, hampers the development of adjustment and limits the efficiency of control. The completeness of control depends also largely upon the breadth of one's past experiences. These psychological factors are

to be taken into account in any ethical theory of responsibility.[1]

Volition is by far the most important of the secondary mental states so far examined. It plays a more prominent rôle in human mental life than any of the primary states, except perhaps perception. The broader working of control which arises in connection with voluntary processes, makes the individual master of his environment to a higher degree than he can attain without it. Man foresees future dangers and responds in such a way as to prevent or overcome them. The ascendency of the expressive side of experience is increased still further in man by language and rational activity (ch. xv).

Collateral Reading:

James, W., Psychology, chs. 24, 26.
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Pillsbury, W. B., Fundamentals of Psychology, ch. 14.
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McDougall, W., Social Psychology, chs. 3, 5, 6.
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Cannon, W. B., Bodily Changes in Pain, Hunger, Fear and Rage.
Dewey, J., Psychology, chs. 18–22.
Thorndike, E. L., Ideomotor Action, *Psychol. Rev.*, 1913, **20**, March.
Washburn, M. F., Movement and Mental Imagery, chs. 8, 9.
Warren, H. C., A Study of Purpose, *J. of Philosophy*, 1916, **13**, nos. 1–3.

Practical Exercises:

Describe the expression of three different kinds of emotion in cases you have witnessed recently.

Analyze some powerful emotion of your own at the time or soon after the outburst has subsided.

Examine your experiences when you plan some course of action, such as how to spend a holiday.

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[1] See Appendix, "Free Will, Determination, and Responsibility," p. 431.

CHAPTER XV

SECONDARY MENTAL STATES (*continued*)

4. Thought and Language

Distinctive Features. — Thought and language combine ideational and kinesthetic elements. To this extent they resemble volition. They differ essentially from volition and from all other mental states so far discussed in two distinctive characteristics: (1) Their ideational components are symbolic. (2) Their development is due almost wholly to the social environment; that is, they arise through the interaction of individuals with one another.

A further characteristic is that thought and language develop together, each furnishing material for the other. Thought is an outgrowth of imagery due to the addition of kinesthetic elements, while language is an outgrowth of conation with the addition of symbolic ideational elements. In thought the kinesthetic element is less prominent than the ideational, and in language the ideational element is less focalized than the kinesthetic. Thought and language are complementary states. Increased definiteness of thought leads to more definite expression in language, while a new verbal symbol is apt to make for greater precision of thought.

Symbolic Character. — In discussing imagery (ch. xiii) we found that a memory image is virtually a reproduction of some perception; a general image is a mental state reproducing certain characters which are common to a number of similar perceptions; images of the remaining types reproduce characters drawn from several perceptions which may or may not be similar. A distinguishing mark of all imagery is that it reproduces certain features which have previously appeared in perception.

Various elements which were not in the original perception of an object become associated with the image. We may regard a thing as beautiful, and a systemic element is thereby attached to the idea. If we picture it as to be avoided or acted upon by ourselves, the image is transformed into a purpose or volition. In the same way it comes about that certain purely arbitrary kinesthetic elements called *names* attach to images of every sort. In adult life the idea of my chum is not a mere image; the name 'Walter' is an integral part of the experience. The general idea of the leading domestic animal is not simply a general image, but an image to which the name 'dog' is attached.

A name is essentially a kinesthetic experience, though auditory and visual elements are usually included with the motor components. Names are first spoken or written or gestured; they are associated with images or perceptions, and in the course of time they become integral parts of the ideational experience. We call them *symbolic* or *arbitrary*, because they rarely belong to the original perceptual experience; they are not part of the external objects which stimulate us.

Arbitrary kinesthetic elements similar in sort to names are attached to other mental states and to their components. The whole group of arbitrary kinesthetic associates are called *words*, and the combination of words with ideational elements is called *language* or *thought*, according as the kinesthetic or ideational components are the more prominent.

For reasons that will appear presently, these arbitrary components tend in the course of time to become focalized. They come to be practically the whole material of the mental state; — the image components which reproduce the characters of the external object remain only as marginal accompaniments. The experience is no longer a picture or replica of the object, but a *symbol*, which may bear no resemblance to it whatsoever.

Social Origin. — The genesis and growth of language is due entirely to the social relations among members of the species. The sole utility of language lies in the fact that it furnishes a medium for *communication* between one individual and another. When I utter the word *dog* or any other word, it is in order to arouse in some other individual an idea or series of ideas corresponding to my own thoughts. It is safe to assume that language would not have developed if mankind had not lived in groups.

Thought is not so essentially social. We think to ourselves in symbolic terms, without reference to the effect on others. But it is difficult to see how thought could have developed without language — that is, without a social environment. Apart from social conditions there is nothing in mental life to make the symbolic element of an idea vivid or focal. Objects, situations, and events furnish the original stimuli. Ideational states are determined by the character of the sensations which these stimuli arouse. Some components in the ideas become increasingly focal, but the vivid elements are pictures of external things or occurrences — not symbols. The non-social idea of 'dog' is the dog's general appearance, his bark, his bite, his characteristic modes of behavior; all of these are schematic reproductions of actual sensations arising from 'dog-stimuli.'

The need for a name is social. We have not always a dog to point to; we can imitate his bark, but not (satisfactorily) his hunting activities. One of the older theories of the origin of language was based on man's imitation of barking, crowing, mewing, etc. This theory meets difficulties when it comes to the naming of fish, fruit, and other 'voiceless' or inactive things. To designate such objects to other persons, and to indicate events and human activities, arbitrary gestures or sounds seem to have been required from the start. Imitative (onomatopœic) names tend to become conventionalized also. Since these kinesthetic symbols are reproducible,

they are highly useful for communication between man and man. They are easier to focalize and control than images. Through repetition they attain greater prominence as components in the ideational states. Hence the symbolic experience of *thought* has tended more and more to supplant imagery in civilized life.

The history of the human race indicates that man rarely invents words except under stress of social communication. Things, creatures, and qualities which have social significance are the first to receive names. The degree of social development of a race may be roughly estimated by the size and character of its vocabulary.

Mutual Dependence. — It is evident from this that thought and language are mutually dependent. The demands of social communication lead to symbolic naming, which takes the form of kinesthetic experiences. These kinesthetic symbols attach to the ideas and transform them into a new kind of mental state. In the type of behavior called *communication* the kinesthetic component is stronger than the ideational, and the mental state is *language*. When the same symbol occurs without communicative expression the ideational component is stronger than the kinesthetic, and the mental state is *thought*.

The growth of each one of these states means the growth of the other. New words add precision to thought. Growth of definiteness in thought leads to the appearance of new words in the language.

It is perhaps too sweeping to say that thought could not arise or did not arise in any race or individual without language, or that language never appeared without symbolic ideas. The examination of known races leads to the conclusion, however, that the development of either of these states beyond a rudimentary stage depends upon the coöperation of the other.

Types of Language. — The chief types of language are

gesture, speech, and *graphic record.*[1] Facial expression is more primitive than any of these, but it is confined to emotional states and does not seem to have attained any symbolic development. Such communicative expressions as winking an eye or contorting the face may be regarded as facial gestures.

Gesture language is probably more primitive than speech. It arose from the practice of pointing to objects or waving the arms to arouse attention. In time some of these gestures assumed a conventionalized form. Certain movements of the hand or head came to denote fish, fruit, fire, cooking; pairs of opposite movements came to signify assent and dissent, or 'come here' and 'go away.' A developed form of gesture language is used in civilized communities among the deaf. Otherwise it occupies a secondary position, being superseded almost wholly by speech.

Vocal expression (speech) is so much more convenient than gesturing that it has developed far beyond the latter. One can readily talk when engaged in fishing, plowing, etc., while gestures disturb these occupations. One can listen to oral conversation without turning the head; it is not so easy to watch the plow and a companion's gestures at the same time. The ears are always open; we can secure a man's attention by speech without stepping in front of him or seizing hold of him.[2] In the sick room or in No Man's Land gestures are more effective than speech. But in normal conditions of life speech has generally far greater advantage.

The graphic form of language is used in civilized communities to supplement speech. It consists in making permanent marks or impressions upon stone, bricks, papyrus, and paper. In the older graphic languages the records were rude pictures of objects; later these pictures became conventionalized,

[1] As modes of behavior they are called gesturing, speaking (or talking), and writing.

[2] The button-holing habit is possibly a survival of the primitive gesture stage.

as in Chinese, or each graphic unit symbolized a syllabic sound, as in syllabary Japanese. In the graphic language of modern western races each symbol (letter) represents an elementary vocal sound, either consonant or vowel. The whole group of different letters comprise the alphabet. The letters of the alphabet symbolize vocal sounds which are themselves arbitrary symbols.

There are several varieties of graphic language, whose distinction is more important from the social than from the purely psychological standpoint. Besides ordinary handwriting we may mention printing, typewriting, telegraphy, and phonography. In all these forms the characteristic feature is the permanent record, which makes it possible for an individual to communicate with others at great distances and after long intervals of time. In fact, the chief rôle of graphic language is to extend the range of communication in space and time. Graphic language, like gesture language, is received visually, except the phonographic variety, which is auditory.

Nearly all graphic languages are asymmetrical. In the Greek and Latin alphabets the record always runs from left to right, in Hebrew and Arabic from right to left, in Chinese from top to bottom. The order is practically never reversed, nor are individual letters turned around.[1] 'Mirror-script' is unintelligible to most individuals who attempt to read it,[2] and it is equally hard to write. Experiment shows that this difficulty is due merely to long fixation of habit; one can in time learn to write and read reversed script quite readily.

[1] By way of exception the Egyptian hieroglyphics run either left-right, right-left, or down the page. As the characters are mostly human or animal forms one can determine at a glance how to read the record — we meet the figures *face to face*, unless the characters run in columns, in which case we read downward. Egyptian writing (and reading) as a motor process is therefore horizontally symmetrical, though the separate characters are nearly all asymmetrical.

[2] See Fig. 67, p. 266.

The asymmetry of graphic language is due to the preference of one hand (usually the right) over the other in intelligent acts; and this is in some way connected with the greater development of certain higher centers in one hemisphere of the brain. The speech center in most individuals is located in the left hemisphere, which controls movements in the right side of the body. The origin of the specific *direction* of writing may possibly be connected with the instrument used: a quill is more easily pulled along; a chisel is more effective when pushed; a brush is more naturally swept down toward the writer.

Comprehension and Reading. — Communication is a two-sided affair. It is not completed, like other types of behavior, when the reaction or response is made. It involves a later receptive process on the part of another being. The spoken word produces complex sound waves, which serve as a *verbal stimulus* to the auditory receptor. The central and conscious effect on a second person is very different from that of other compound clangs. The sensory components of the experience are very indistinct. They serve mainly to arouse an ideational state, which is a thought similar to the thought experienced by the first person in speaking the word. The mental process of receiving verbal stimuli derived from speech or gesture is *comprehension.*[1] It results in an ideational state which is usually a thought, though at times it may be an image.

The graphic record produces a visual stimulus. The receiving process is much the same as in comprehension, except that the succession of experiences is more under the control of the second person. By moving the eyes slowly or rapidly he can regulate the speed with which the verbal stimuli are presented. The receptor process for graphic stimuli is called

[1] Oddly enough there is no English word which denotes the process exactly. *Comprehension* is used here in a slightly technical sense. *Understanding* includes both *comprehension* and *reading.*

reading. The resulting mental states are thoughts with occasional imagery.

The distinction between ordinary sensory stimuli and verbal stimuli is important. The physical material is the same in both — sound waves or light waves; but their central effect is radically different. This is illustrated if we have some one read us selections from a book in some unfamiliar language, interjecting here and there an English phrase. Or we get the effect when we glance over the pages of a Japanese book with an occasional English quotation.[1]

Nature and Types of Thought.—The ideational states of civilized man consist almost wholly of thoughts. The *word* 'horse' is for most of us the dominant feature of the horse-idea. We picture vaguely the appearance of horses, their movements, the sounds which they make in galloping or neighing; but the central feature in our idea of a horse is the name or word.

For some individuals a word is preëminently a sound ('Horse!'). For others it is the adjustments of throat and lip muscles, with the kinesthetic sensations which they arouse. For others it is the printed word as it appears to the eye; or it may be the kinesthetic sensations of writing the word. In many cases the experience combines two or more of these factors. When we think of a horse the verbal symbol of whatever sort forms the chief component of the thought — the other elements lie dim in the background. In abstract thinking ($2 + 2 = 4$) verbal symbols constitute practically the whole experience.

Since words bear no similarity to the objects for which they stand, they are better material to work with than general images. When new varieties of a given species are discovered the general image may require considerable reconstruction,

[1] *Reading aloud* is a further complication of the communicative process. The reader acts as a 'relay' between the imparting and the receiving individuals.

but the verbal name does not. The general image of 'swan' had to be quite made over when black swans were discovered, but the word was unchanged, except for adding a 'dot of black' to the mental background.

In civilized man general imagery tends to be supplanted by symbolic images or thoughts. Your idea of *specific* objects and beings may be a free image, with the name a minor feature of the experience. The idea of your chum, your dog, your watch, is probably a sort of composite picture of many perceptions; the *name* William, Rover, 'my watch' is a relatively unimportant element. With ideas of general classes or sorts of things or events the opposite is true. Here it is not the general image, but the symbolic name that plays the chief rôle. When you think of paper, stairs, piano, dressing, eating dinner, etc., the image of the thing or act is relatively unimportant — the word is the dominant part of the experience. The association between the name and its object is firmly fixed in the individual because it prevails in the community generally. The arbitrary nature of words appears strikingly when we move into a community where an unknown language is used.

Imageless Thought. — Recently there has been considerable discussion among psychologists in regard to 'imageless thought.' A number of careful investigators report that their thoughts lack entirely the character of imagery. Others are inclined to question these reports. The conflict of opinion is probably due to different interpretations of the term *imagery.* Popular usage applies the term almost wholly to visual data. In psychology organized auditory, tactile, and kinesthetic ideas, so far as they exist, are called images. But the kinesthetic verbal elements may not be images at all; they may be actual sensations. It is quite possible that for some individuals thought consists wholly of kinesthetic sensations — or nearly so. For such persons the thought of a horse may consist of adjustment of the larynx and other

vocal muscles preparatory to uttering the word 'horse.' It is then a sensory mental state, not an image.

For most persons 'external' ideas of sight, hearing, and touch enter into the thought experience. When any summation of nerve impulses occurs, modification takes place. On the subjective side, when any combination of mental data occurs there is a process of transformation. Hence, as thoughts develop the components are gradually transformed, till at length the 'thought' state comes to be wholly unlike the 'image' state from which it is derived. This is especially the case if several different types of imagery enter into the thought. In the end the thought is likely to lose the distinctive character of each type; the experience then becomes a composite, in which the several sense-modes are fused together into a new quality. One may readily test whether this is true in his own case by examining certain typical thoughts. Possibly 'imageless' thought is due to this transforming process. The original image components may become so transformed in the course of time as to lose all recognizable semblance to any sense qualities.

Meanings and Values. — The experience called *meaning* is part of the thought state. Meaning comprises those elements in the thought which are not symbolic, but which resemble the object or situation. When we think of *man* the symbol or word forms the central feature (focus) of the experience. Along with the word there may be in the background or margin of the thought a fleeting image of some specific man or of certain human characteristics. These non-symbolic factors in the experience constitute the meaning of the thought.

When the neural impulse which we observe as a thought experience occurs in the brain, these image components are aroused simultaneously with the symbolic elements; they give a "tinge of reality" to the experience. This imagery tinge is the *meaning consciousness*. In other words, the

meaning of a thought comprises those elements in the experience which correspond to the object or situation, as distinguished from the mere verbal or symbolic elements. When we endeavor to examine the meaning of a word, what happens is that these marginal elements become focalized.

The psychological character of meaning may be observed by comparing the mental state aroused by 'meaningful' words with nonsense. There is a vivid tinge of imagery for most of us when we see or hear such words as *sacrament* and *delicious*, which is missing in *luntosity* and *pelegation*. No meaning attaches to the visual presentation of the sentence: "Isle *of* use wheat tart"; but the auditory presentation of the same sentence fairly glows.

Psychologically speaking, the *value* experience is similar in type to the meaning experience. Meaning comprises the ideas of certain qualities of an object or event; value consists of ideas of intensity, duration, and other quantitative characters. We stated that an image differs in intensity from the perception which it represents. The same is true of a thought. We can compare the intensity of two perceptions, feelings, or conations, and repeat the comparison in imagery and thought. If we associate the words 'six ounces' with one lifted weight and the words 'four ounces' with another lifted weight, we have the wherewithal to compare the intensity of these two experiences when they are reproduced as images or symbolized as thoughts. Such quantitative ideas are attached to perceptions, images, and thoughts. They usually enter into thought experiences as mere marginal elements and constitute the value-coefficient of the experience. When we think of an object or event a slight 'value tinge' attaches to the symbolic word, in the same way as the meaning tinge attaches to it. This is especially the case with thoughts in which quantitative characters are prominent. My thought of a certain book is usually tinged with some such ideational elements as large or small, long or short,

difficult or easy reading, true or false. When these ideational elements become focal, the state becomes a value experience.

Value experiences which involve social situations are generally rich in systemic components. The thought of a good or a bad action is generally accompanied by the feeling of desire or aversion. There is also in most cases a kinesthetic tinge other than the language component. We tend to *act* upon the value experience. Where these hedonic and expressive components are focal, the experience is no longer a thought, but belongs to the class called ideals, which will be discussed presently. Some writers confine the term *value* to this higher mental development. But value experiences of the higher type appear to be essentially the same as the thought of long or short, quick or slow, etc.; they are best understood when regarded as an outgrowth of these lower stages.

It should be noted that the ideational values of an experience may be quite different from its perceptual or sensory values. A 'trivial' event from the perceptual standpoint may 'loom big' in our scheme of life when regarded from the standpoint of thought and social relations. And again, the ideational value of an experience may vary widely in different circumstances. At one time we may attach slight value to some event, such as the killing of a usurper; later we may come to regard it as a turning-point in history.

It appears, then, that there is not so close a correspondence between the 'objective' values of situations and events and our subjective experiences of value in the sphere of thought, as in the sphere of perception. As psychologists we deal only with the *value experience;* it belongs to the economist, the artist, and the moralist to adjust our appreciation of situations and events to the 'values' of objective reality.

To sum up, meaning and value are primarily those elements in the thought which correspond to the object or situation

outside of ourselves which aroused the original perception. Meaning is the component in an experience which corresponds to qualitative characters of things, while value corresponds to their quantitative characters, such as intensity, duration, size. As our thought life advances, the feelings, conations, and social situations induced by perceptions take on meaning and value elements also. In most ideational experiences the meaning and value components are obscure and marginal, but at times they become attended to or focalized. This leads to the specific types of thought known as meaning and value experiences. The thought itself may be not of a man, but of his ethical value; we may think not of a political procession but of its social significance.

Rational Thought; Concepts and Judgments. — Conception and judgment constitute a higher level in the development of thought. These states are known as *rational thought.* In rational thought the meaning elements or the value elements become focalized; the verbal elements do not become marginal, but they are less distinct than in ordinary thought.

The thought of an object or event in which the meaning or value is thus focalized is called a conception or *concept.* When I think of a horse with the meaning uppermost, certain characters, such as *vertebrate, ungulate, wagon-pulling, domesticable,* are in the focus of the experience. The concept of horse is a thought in which some or all of these meaning elements are more vivid than the verbal symbol. When I think of *four* or *short* or *stocky* the thought is a value concept.

A *judgment* is a mental state which combines two concepts, that is, two meaning or value elements, both of which are focal. The fusion of two thoughts does not constitute a judgment unless some of their meaning elements are similar. The thought of man combined with the thought of a horse may produce the thought of a centaur, but this is not a judgment. If, however, we combine the concept of horse with

the concept of vertebrate, we obtain the judgment "Horse — vertebrate," — or as it is generally expressed in language, "A horse is a vertebrate," or, "All horses are vertebrates." When we think of a certain light and of intensity and combine the meaning with the value, the resulting thought is the judgment, "This light is bright."

If both of the focal elements are meanings the experience is called a *meaning judgment*, if one is a value, the experience is a *value judgment*. Judgments are also classed as *particular* or *universal*, according as the leading component is due to a single perceptual stimulus or is a generalized thought derived from many experiences. In particular judgments one of the focal components may be a perception, instead of an idea. ~~Here is an exceptional case,~~ in which a perception forms part of a secondary mental state.

Since thought tends to expression in language, both types of rational thought have corresponding types of *rational expression*. The language equivalent of a concept is a *term;* the equivalent of a judgment is a *proposition*. The thought 'horse — black' as a judgment may be instantaneous, but as a proposition the experience begins with one term and the other term arises later. This experience involves succession of mental states (ch. xvi).

In examining these higher developments of thought the psychologist is concerned only with the nature of concepts, judgments, terms, and propositions as mental states, not with the science of logic as such. If our analysis is correct, a mental judgment does not consist, as many logicians believe, in the discovery of relationships among 'classes.' As a subjective experience a judgment is a combination of certain meanings or values which attach to thoughts. A proposition is the expression of this rational experience in language. The formation of concepts depends upon *similarity* in meanings or values, and this similarity may usually be traced back to similarities among perceptions.

Rôle of Thought and Language in Mental Life. — It is scarcely possible to exaggerate the importance of thought and language in the mental life of man. On the receptive side they give a finishing touch to the integrative process; on the motor side they perfect the coördination of activity to a far greater degree than conation and volition. They transform the central adjustment process into *rational control.* They furnish two new modes of intelligent behavior, *communication* and *rational expression of thought,* over and above the trial-and-error learning of subhuman species. Taken together they provide a tremendously effective mechanism for the adaptation of response to the conditions of the environment.

More than any other mental state except perhaps emotion, thought and language must be studied in the light of their history. But whereas emotion is a survival from ancestral conditions, thought and language are brand-new human acquisitions. They are still in the making.

An important feature in the growth of language is its slow evolution in the race and its rapid development in the individual. New words arise phylogenetically by a gradual process, as the sphere of thought in the race enlarges. Once adopted they are transmitted to the bulk of individuals in the community and are readily learned by children or adolescents. Much the same is true of thought. The growth of thought depends intimately upon the existence of words. If the vocabulary of a community is scanty its range of thought is limited. Given a rich vocabulary, the best organized individuals in the race quickly attain a wide range of thought. In the sphere of thought, more than in any other type of mental state, we find tremendous individual differences in capacity and development. Such differences appear especially in the realm of rational thought.

The development of thought and language in the individual depends not only upon the social environment, but

upon inherited nerve structure. To bring about these mental states the higher receptive centers must be connected by association tracts with various motor centers. Gesture language depends for its development upon the ready establishment of connections between the visual center and the center for arm and hand movement. Vocal language involves inherited pathways between the auditory centers and the centers for vocal expression. Writing involves pathways between visual or auditory centers and those for finger movements. The intricate inherited organization of the human cortex accounts for the superiority of the human cognitive life over that of lower species.

5. Ideals and Rational Actions

Their Nature and Classification. — *Ideals* and *rational actions* are the most composite of all mental states. They combine ideational, hedonic, and kinesthetic elements. In general the ideational components are most prominent. The social factor ordinarily plays an important part in forming these states, but they are not essentially social like thought and language.

An ideal consists of a vivid image or thought, which is combined with an intense feeling and with intense kinesthetic elements. If one's ideal is to become a teacher, he has a general image or usually a highly complex thought of the various characteristics of this profession; he is also stirred by a noticeable feeling when he thinks of it; and his acts with their kinesthetic accompaniments are such as will tend to fit him to become a teacher. In other words, an ideal involves thinking a thing, feeling it, and doing it.

Usually our ideals develop gradually out of particular experiences in which one or other of these elements predominates. The experiences which lead to ideal-formation are largely social. We are told by parents and friends that we are fitted for a certain career; an ideal is aroused by our con-

tact with someone who has been successful in this direction, or is inhibited by some conspicuous failure.

An ideal is the outgrowth of many separate experiences. It is a 'composite picture' of many thoughts, volitions, sentiments, and emotions, all of which bear upon one and the same type of situation. For these reasons our deepest-rooted ideals have usually grown up slowly and are related to a host of separate experiences. The elementary constituents of ideal states are often present as marginal components in the general 'stream' of mental life. These marginal ideals determine our motor expression; they are termed *motives* of action. Only on occasion do ideals become focal, so that we are intensely aware of our general aims in life.

Ideals are classified according to the type of mental state which predominates among their components. They include

Scientific ideals
Esthetic ideals
Ideals of power or accomplishment
Moral and religious ideals

Ideals occur in various degrees of subordination. Highest of all is our 'life ideal,' which marks the general trend of our career. Beneath that may be the ideal of some specific line of work. Subordinate to this is the ideal of our general course of action during the next few months or years. Lowest of all are specific ideals or motives of daily action. In both higher and lower ideals the dominant factor may be scientific, esthetic, or dynamic, as well as moral. Owing to the dominance of social organization in modern life, moral ideals rank highest in importance. But a study of mental life shows the presence of other types to a greater extent than is ordinarily recognized.

In civilized man the thoughts which enter into ideals are generally rational thoughts. Hence, when an ideal issues in motor expression the resulting mental state belongs to a higher level than volition; it is called *rational action*. Civilized man

acts systematically, in accordance with certain general rational principles which grow out of rational thought; his scheme of action may be scientific or esthetic or practical or moral. These general principles are formulated in the organized branches of learning called science, esthetics, practical training, and ethics. But even apart from the definite formulation of general principles our activities tend, as they become organized, to rest upon judgments instead of ordinary thought. That is, *human activity tends to become rational.*

Even the uneducated man acts to a certain extent rationally. When he breaks an arm or dislocates an ankle he calls in a surgeon; he is not content, like his primitive ancestors, to hang an amulet over the injured member or rely upon magic words to effect a cure. When he sets out to become a mechanic he takes a course of preparatory training instead of learning by mere trial and error. And the same in any branch of artistic activity.

In the sphere of social action the rational character is even more fundamental. We do not hesitate to eat food near a marble statue, but we shrink from eating near a starving man. Human beings in whom rational thought life is well developed act with constant reference to the social environment. Their actions are influenced by the thought that other men are beings like themselves. Their behavior assumes a new and higher type, called social or moral *conduct.*

Not only is our own behavior modified by rational thought and by our thought of others, but we appraise the actions of other men according to the same standard. We judge their behavior with reference to rational and social conditions. In other words, we appraise human activity not as a series of instinctive or mechanical movements, but as examples of *rational actions* and more especially as *social conduct.*

Summary of Mental States. — The elementary data derived from the external, systemic, and motor senses, and the

corresponding ideational elements, seldom occur separately in adult mental life; they combine to form *mental states* which vary tremendously in complexity. For convenience these states are classed as *primary* and *secondary*, according as they involve one kind of data or more than one kind. The relation of the mental states to their elementary data was shown in Table XIII (p. 231).

Perception is the most important of the primary states (ch. xii); *imagery* is more important than *feeling* or *conation* (ch. xiii).

Of the secondary states, *emotions* are the most primitive. They rest upon ancestral conditions, and in many cases prove a hindrance to the adjustment of response to stimulation under present conditions of life. *Sentiments* are the least important type. *Volitions* constitute a distinct advance in mental organization (ch. xiv). *Thought* and *language* (and *ideals* and *rational actions*, which develop out of them) are the most modern types of mental states and are by far the most important factors in mental life. They depend essentially upon social interaction of individuals and are peculiarly suited to bring about adjustment between the individual and his total environment. These types are still in course of active development in the human species. *Rational thought*, a special variety, is the most important single phase of mental life that has evolved up to the present (ch. xv).

Physiologically, the formation of mental states is due to the *summation* of impulses in the cortical centers and the *modification* which this summation entails. In subjective terms, this is observed as a process of *combining* sensations (and ideas) into a single experience, which is *transformed* qualitatively in the process of combination. *Retention*, *metabolic change*, and *distribution* of impulses also enter into the central process, and are observed as *revival*, *vividness*, and *discrimination* of mental states.

The development of specific mental states is due to the coöperation of three general factors: (1) Complex inherited cortical structure; (2) Specific forces in the general environment, which act upon the given individual; (3) The social environment. The part played by social stimuli in molding mental states differs so widely from the influence of the general environment that the two may properly be treated as distinct factors.

COLLATERAL READING:

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Judd, C. H., Psychology, General Introduction (2d ed.), ch. 10.
Titchener, E. B., Experimental Psychology of the Thought Processes, chs. 4, 5.
Titchener, E. B., Text-Book of Psychology, secs. 139–147.
Angell, J. R., Psychology, chs. 10, 11.
Breese, B. B., Psychology, chs. 13–14.
Urban, W. M., Valuation, chs. 2–5.
Stout, G. F., Manual of Psychology, Book IV, ch. 5.
Calkins, M. W., First Book in Psychology, chs. 9, 10.
Stoerring, G., Mental Pathology in its Relation to Normal Psychology (trans.), chs. 9–11.
Wundt, W., Völkerpsychologie, Vol. I, Die Sprache.
Dittrich, O., Die Probleme der Sprachpsychologie.
Müller, Max, The Science of Thought.
London, J., Before Adam (especially ch. 4).

PRACTICAL EXERCISES:

What constitutes your thought of *university, idiot, symphony, Egypt, steamboat, doxology, medicine, penitence?*

Ask someone to read aloud, and at the same time to think of other things; note how far his distraction interferes with pronunciation and especially with the inflections of voice which "give the sense."

Examine how some ideal influences your plans of life.

CHAPTER XVI

SUCCESSION OF MENTAL STATES

The Stream of Conscious Experiences. — In the four preceding chapters we have examined the various types of mental states. Mental life consists of a succession of these states. One neural process is followed by another, or in passing from center to center it undergoes modification so that the mental state is virtually transformed.

The rise of a *new* mental state is due to the occurrence of some new stimulus. When we are reading and a loud noise occurs, the visual perception and thought give place to auditory perception. The *transformation* of mental states occurs when the impulse, in passing from one neuron to another, is modified by the condition of the second neuron. This is observed in a train of thought, where the word ' pyramid ' suggests the great pyramid of Egypt, this in turn suggests the Nile, and so on.

The succession or flow of experiences in mental life has been aptly called by James the *stream of consciousness.* In investigating this ' stream ' we should bear in mind that it is also a stream of neural impulses. In fact, the causal explanation of the succession and transformation of experiences from moment to moment may be said to rest upon the physical and chemical properties of nerve.

The psychologists of the 18th and early 19th centuries, particularly those of the English school, formulated certain laws of the succession of thought. This succession they termed " association of ideas." They made little effort, however, to connect these laws up with the laws of neural activity.[1] A

[1] David Hartley attempted this, but his treatment was based upon a crude conception of neural operation and was abandoned by later writers. The English associationists based their explanation of mental life almost wholly

more serious defect in their work from the standpoint of subjective observation is that it ignores almost entirely the succession of perceptions, feelings, and conative experiences which play an important rôle in mental life.

The succession of ideational states (memories, general images, fancies, thoughts) depends almost entirely upon central transformation of impulses. Succession of perceptions depends largely upon change of external stimuli. These constitute essentially different types of successions. But in actual life our ideational experiences are frequently broken in upon by perceptions and other sensory experiences; our perceptions are often supplanted by ideas or are transformed by ideational accompaniments. Hence, the general succession of experiences in our mental life includes both types. We shall examine first the succession of perceptions and other sensory data, then the succession of ideational experiences, and finally the general succession of experiences in mental life.

Stream of Perception. — A large part of our mental life is the direct result of external stimulation. This *stream of perception* depends primarily upon conditions in the environment. The stimuli which affect our eyes, ears, skin, semicircular canals, nostrils, etc., are due mainly to forces outside of our own body,[1] which are for the most part independent of our mental processes. As a result, we do not control the flow of perceptions in the same way that we control our feelings, movements, and ideas.

By closing the eyes we can remove most of our visual perceptions; we can turn the head and alter them. We can reduce the intensity of an auditory impression by stopping the ears. A slight movement may serve to get rid of a sensation

upon the association process. Their attempt to build up a complete psychology upon the laws of association was extremely useful in that it led to careful psychological analysis. But the theory was one-sided. There are many other mental operations besides suggestion.

[1] The eye is also stimulated by the retinal circulation; a vascular stimulus gives 'buzzing' in the ears. These internal stimuli have usually little effect.

of touch, warmth, or cold. By locomotion we are sometimes able to alter our entire external environment. But even these changes are only partly under neural control. When we move from one environment to another the actual stimuli are as much beyond our control as before.

In other words, we are not able to mold and control perception as we mold and control other types of experience. I can readily arouse the image or thought of my brother; but I cannot arouse a perception of him if he happens to be a hundred miles away. I can arouse the image of a rose and the feeling of pleasure at its form and odor; but I am unable to bring about a perception of its form or a sensation of its odor if there is no rose present in the environment to stimulate my receptors.

Our control of perception, then, is largely inhibitory in character. We can reduce a perception to the margin of consciousness by attending to some other experience or by closing the eyes, walking away, etc. Or we can modify a perception by adding images or thoughts to the experience. But we have little power to produce a stated perception at any time. The ultimate source of perception lies in the world outside of us.

The chief rôle of the nervous mechanism in connection with the succession of perceptions is (1) to focalize some perceptions and render others marginal, and (2) to select from among a number of possible perceptions by means of motor activity.

Generally the perceptions which are focalized or selected are those that serve our purposes and ideals in life. The growth of central control depends upon two factors: (1) learning to distinguish certain kinds of stimuli, and (2) the fitness of certain stimuli to nourish us, protect us, and adjust our relations with the environment. Given two individuals in the same general environment and subject to practically the same external forces, one perceives one set of objects and events, the other may perceive quite a different set. A great number

of people were passing the corner of Broadway and Wall Street at 11 o'clock last Thursday. All were subject to practically the same external conditions, but if they were asked to state what they saw, heard, and experienced generally, their reports would show tremendous differences. The newsboy watches to see what faces are attracted by his cries and the headlines, and what hands reach into the owner's pocket. The farmer notices the fruit stands and the horses. The broker's clerk observes shreds of ticker tape and certain buildings which he is accustomed to visit. The student of psychology is impressed with the throng of people and studies the expression of their faces. The beggar is on the lookout for very different expressive signs. In a word, from the total mass of stimuli which affect our external receptors at any time, we pick out certain kinds which have become familiar through repetition and which fall in with our life interests.

Laws of Perceptual Succession. — The rôle of the two factors, external stimuli and neural functions, in the succession of perceptions may be stated in the following laws:

(1) The succession of perceptions depends primarily upon changes of external stimuli.

(2) It depends upon the manner and conditions of stimulation. The same visual stimulus produces a different effect (i.e., the perception is altered) according as it strikes the center of the eye, the periphery, or the back of the head.[1]

(3) It depends upon the retention effect of previous similar stimuli. Repetition and retention improve one's ability to pick out certain stimuli and combine them into perceptual states.

(4) It depends upon present metabolic conditions. These result in inhibiting certain perceptions, focalizing others, and retaining others in the margin.

(5) It depends upon kinesthetic stimuli. Motor activity enables us to get rid of certain stimuli and substitute others —

[1] In the last case it does not serve as stimulus at all

as when we leave the city for the country or attend a concert to hear a certain piece of music.

The succession of perceptual experiences depends upon these five conditions. All but the first are functions of the receptors and of the nervous system.

Stream of Thought. — The adult mental life of civilized man often includes a long succession of ideational states uninterrupted by perceptions. Perceptual elements as well as systemic and kinesthetic may appear among the components, but the dominant character of the state is ideational — either some sort of imagery, or a thought. The starting point of such a series is always a perception or some other type of sensory experience, but the train of ideas, once started, may proceed for a long time without interference by sensory states.

In subhuman species prolonged trains of ideas apparently do not occur. If an animal experiences a memory image or an image of any sort, this mental state either leads directly to motor expression, or it is immediately succeeded by some new perceptual experience.

A dog gives evidence of remembering his master after prolonged absence, but instead of this memory starting a train of reminiscences, it leads at once to barking, frisking about, and vigorous wagging of the tail. Even while the memory image lasts it may be interrupted by a word or gesture from his master which introduces a new sensory experience. In lower animals the image life is even more fragmentary.

In man the image life, and more especially its higher form the thought life, tends to become one of the most important phases of mental life. A perception arouses a thought, this thought excites another thought, this in turn a third, and so on. Thus a long series of thoughts may arise in quick succession, each independent of external stimulation except at the very beginning.

Laws of Ideational Succession. — The succession of ideational processes (imagery and thought) is usually called *association of ideas.* Psychologists early discovered certain uniformities in the mode of succession, which were formulated as "laws of association," or laws of suggestion. These uniformities were first noted by Aristotle, who is responsible for the laws of contiguity, resemblance, and contrast. Hartley, James Mill, and their followers elaborated the laws, but rejected contrast as an independent mode.

The recognition of the laws of association in thought is of practical importance, since the average man is inclined to regard the succession of his thoughts as due to mere chance or mere volition. At times we seem to create new thoughts quite arbitrarily and with no reference whatever to previous experiences. We see no reason except pure chance why our thought of a trip to the city should be succeeded by the thought of John Bunyan. Or we attribute the connection to some subconscious force or underlying personality.

Actually, the succession of thoughts is due to the opening up of synaptic connections between neurons, and probably also to modal changes in the nerve impulse as it passes from one central neuron to another. Apart from the intervention of sensory elements during the process, the succession of ideational states depends wholly upon the past and present condition of our nervous system.

The neural process specially characteristic of succession is *conduction* (ch. iv); the corresponding conscious process is *suggestion.* The laws of ideational succession may be stated either as laws of associative suggestion or as laws of neural processes.[1]

(1) Law of Similarity: A perception or idea tends to suggest a similar idea. — When we see a stranger we tend to think of a friend whom he resembles; or again, the thought

[1] The neural interpretation of these laws is still a matter of theory. See Appendix, "Neural Activity," p. 435.

of Mr. Tubbs may lead us to think of Mr. Hubbs because the two names are similar in sound. The thought of Cæsar leads many to think of Alexander or Napoleon, because the careers of these three men bear many resemblances to one another. — Stated in neural terms, an impulse in one neuron tends to pass over into another neuron which has been similarly excited.

(2) Law of Contiguity: A perception or idea tends to suggest another idea which was previously experienced near it in space and time. — When we hear the opening strains of the Lohengrin Wedding March the perception arouses the image of the following tones; the thought of sunset may arouse the thought of night. Or again, the thought of a cup may lead to the thought of the saucer; the memory of a house may bring up the memory of a certain room. In the first two instances the contiguity is temporal, in the last two it is spatial. — In neural terms, when a complex impulse passes into a neuron whose trace is partly similar in mode it tends to be modified by the non-similar features of the retention trace of that neuron. This means that when the impulse passes into the second neuron it tends to become more like the previous impulses which affected that neuron.

The laws of similarity and contiguity may be combined. The similarity between two ideas or two objective things means that they are partly congruent and partly different. Suggestion means that when the 'same' elements recur in thought they lead to the reinstatement of accompanying dissimilar elements. But the unlike elements are reinstated through contiguity. For example, I think of the World War, and this leads to the thought of the peace of Westphalia. Certain elements in the idea of war are the same for any war; to these identical elements are attached contiguous experiences which are dissimilar in the two cases. The identical elements in the two experiences lead to the reinstatement of certain dissimilar elements present in the earlier experience.

This LAW OF REINSTATEMENT may be expressed as follows: A mental state tends to reinstate a previous mental state, part of whose constituents are congruent with the former.

It is obvious from this that one idea may lead to a number of different associations. The word 'beware' sometimes suggests 'pickpockets,' sometimes 'a widow.' Just which one of these actually follows depends upon other conditions, which are expressed in other laws of association.

(3) LAW OF FREQUENCY: An experience which has been *repeated* many times tends to be suggested in form of a memory or thought more readily than an experience which has occurred in the past only once or a few times. — We recall the name or looks of a friend much more readily than we recall a stranger. The same phenomenon appears in language; we recall and repeat far more readily phrases which we have memorized than those which we have read or listened to a few times only. — In neural terms, repetition improves the synaptic connections between neurons and thus facilitates the future passage of an impulse along the same path.

(4) LAW OF VIVIDNESS: Among alternative ideas which might follow a certain mental state, that idea tends to be suggested which was more intense or *vivid* when it occurred previously as a perception or thought. — We tend to recall more readily an important event or thrilling experience which we have undergone; we are most apt to recall vivid pictures and clean-cut phrases. — In neural terms, an intense impulse tends to modify in a marked degree the neurons through which it passes, and this renders it more likely to affect future experiences.

(5) LAW OF RECENCY: A *recent* experience tends to be suggested as a memory or thought more readily than an experience which occurred some time ago and has not been repeated meantime. — We recall, for example, many more experiences of the past week than events which occurred during some week a year or ten years ago. — In neural terms,

a synaptic connection which has been recently used is more permeable than a path which has not been used for a long period of time. Connections in the central nervous system tend to become resistant through disuse.

The factors of *frequency*, *vividness*, and *recency* interact and modify one another's effects. Thus a vivid experience which occurred many years ago may be suggested more readily than a recent experience of lesser vividness. Frequent repetition may strengthen a remote experience, or on the other hand an experience which has not been attended to or focalized may not be recalled even though it has been repeated many times. It is difficult for us to memorize a set of instructions on a subject which possesses no interest, no matter how many times we rehearse them.

Classes of Associations. — Experimental psychology has investigated the strength of various sorts of relationship in producing suggestion. In addition to *spatial contiguity*, *temporal contiguity*, *objective similarity*, *verbal similarity*, and *contrast*, the general image and symbolic thought introduce certain logical relationships. These include *coördination* (of two general ideas of species belonging to the same genus, such as red — yellow, both being colors), *subordination* (table — leg, vertebrate — man), *cause and effect* (fire — heat), *means to an end* (listen — hear). Investigators have examined, among other problems, the comparative frequency with which different sorts of relationship occur in association and the comparative length of time required to form an association of each sort. [Table XVIII.]

Control and Limitations of the Thought Series. — The succession of thoughts is to some extent subject to personal control. Repeated experiences of the same general sort build up not only general images and thoughts, but *attitudes* (ch. xvii), which determine the direction of the stream of thought. In addition, a dominant thought may persist during a long period, and may form a 'core' or nucleus

TABLE XVIII. — CLASSES OF ASSOCIATIONS

	Frequency Percent	Time (σ) Aud. Stim.	Vis. Stim.
Verbal	27.89	2083	1972
Auditory or visual similarity	4.05	2088	2425
Completion of words	23.84	2082	1866
Meaning	59.82	1949	1992
Perceptual relations (5.61%):			
Spatial and whole–part relations	3.86	1851	1811
Temporal relations	1.75	1847	1801
Rational relations (31.45%):			
Contrast	9.45	1356	1752
Similarity	4.03	1543	2017
Synonym	5.57	1819	1728
Subordination	1.12	1780	1621
Specification	1.12	2513	1979
Cause	2.21	2044	2333
Effect	2.37	1884	1799
Other relations	5.58	1649	1761
Connections (22.76%):			
Spatial or temporal connections	3.83	2613	2094
Predication	18.93	2301	2363
Manifold relations	8.36	1796	1853
Mediated associations	2.21	1996	2146
Unidentified	1.72	2247	1824

Relative frequency of various types of association and time required to form them (in sigma, 1000ths of second) when the stimulus word was presented auditorially (22 subjects) and visually (3 subjects). Total stimuli: 6162 auditory, 630 visual. [From A. Wreschner, *Die Reproduktion und Assoziation von Vorstellungen*, pp. 261–2. The classes have been consolidated in some cases and the general classes renamed.]

around which other thoughts are successively gathered. Such a dominant idea may produce a general 'set,' which controls the direction of our thinking at some future time. We impress upon ourselves the thought of an important engagement at 5 o'clock. The thought passes, but at 5 o'clock recollection occurs — in most cases; not always, alas. These central impressions are often assisted by external cues; we tie a string around the finger or hide a stocking before going to bed. More effectively, we enter a note on a memorandum

or place an empty cigar box inside our hat. All such mental and physical operations are systematic adaptations which form part of the general function of central control. They involve the processes of successive thinking, whose workings are formulated in the laws of suggestion.

A train of thought once started continues indefinitely. (1) It may be checked by some strong sensory stimulus, which produces a vivid sensation and thereby reduces the ideational state to the margin. We are aroused from thought by hearing someone call or by the presence of some new object in the field of vision.

(2) A train of thought may be checked by the discharge of the nerve impulse into a motor pathway, resulting in motor activity. The sudden thought that it is time to attend a lecture ends our reverie, if the thought passes into immediate action.

(3) Swooning, sleep, and hypnosis may inhibit thought or impede its progress. In a swoon or coma the central process is reduced to a minimum intensity or disappears entirely. Sleep and hypnosis do not affect the thought processes so profoundly as they affect sensations. In sleep, sensory stimuli are generally ineffective; sensation is greatly reduced, but in many cases trains of imagery and thoughts take place. In hypnosis sensations are largely marginal, and ideational states are dominant; the flow of thought is controlled to an unusual degree by verbal stimuli.

Sleep and Dreams. — Sleep is an important factor in our vital life. In man it covers about one-third of the entire day and is an essential part of the organic repair process. The period of sleep enables the organism to restore the material used up by the activities of waking life. Anabolic processes predominate during the sleep period. As a physiological condition, sleep is just as normal as waking life, but the mental processes (*dreams*) which occur during sleep present many unusual if not abnormal features.

During sleep the central nervous activity is greatly reduced in intensity, though in many cases it is still sufficiently intense to be focal. The distinctive fact in dream states is that the central neurons are almost wholly cut off from their sensory and motor connections. The synapses which join the sensory paths with the brain and the brain with the motor paths become highly resistant. Only intense sensory impulses penetrate to the higher centers, or impulses which play a prominent part in our mental life. On the other side of the arc, motor discharge is checked, so that an idea which in waking life would lead to speech, locomotion, or some other coördinated activity either remains without any motor expression, or at most produces a rudimentary effect.

During sleep we are not centrally affected by ordinary sounds, lights, odors, etc. A very loud sound may penetrate to the centers and arouse us; or a sound which possesses unusual personal interest, as when the child's fretting wakens the mother. Organic stimuli are often very effective; the unpleasant and terrifying dreams known as nightmares are attributable to indigestion. Temperature stimuli suggest dreams of a conflagration or of walking the streets unclad. Tactile stimuli are rarely effective.

On the motor side the autonomic processes proceed much as in life. The breathing is more regular and may take on a new rhythm. Occasionally a strong motor impulse breaks down the resistance, as when we turn over in bed or talk in our sleep. Sleep-walking occurs when specially strong motor impulses find effective expression without wakening the sleeper. The very beginning of such movements serves to waken most persons, but in certain individuals and under certain conditions *somnambulism* proceeds in a coördinated manner. The same is true of sleep-talking. Where the motor impulse does not produce actual movement, it is found in many cases that slight twitching movements of the feet, arms, fingers, and throat occur. These incipient

movements are probably more common than is generally supposed.

There is usually no indication to an outside observer that any memory or thought process is taking place, and the sleeper himself may recall nothing on waking. This negative evidence is not conclusive proof that the higher centers are quiescent; for the connection between sleeping thoughts and waking thoughts is often very slender, and we frequently recall a dream immediately after waking only to lose all recollection of it soon after. Accordingly, when one declares that he never dreams we can only infer that he is unable to *recall* dreams. On the other hand, the fact that many dreams are forgotten does not justify the sweeping conclusion that we always dream during sleep. Certain of the higher centers are quiescent at one time or another, and it may be that for some sleepers every higher center is at rest.

Dream experience differs from waking experience principally in that the central field is narrowed; certain central areas are cut off from the sensory and motor pathways. This seems sufficient to explain the fantastic character of dreams and the absurdities which they exhibit. Since our brain centers are largely cut off from sensory impulses, their activities consist chiefly of imagery and thoughts. Dream images may not be actually more intense than the imagery of waking life; but since there are no sensations with which to compare them they become for the time being the most intense and vivid mental states we are experiencing. When I picture a book or a man in waking life the image shares the field of conscious experience with many perceptions. Compared with these it is far less intense and is usually less vivid. In dream life the book or the man appears to be actually before us.

Again, in dreams events proceed in most absurd and inconsequent fashion. I take a party of friends out motoring; an instant later we are gliding along through a narrow canal. I leap to the bank and ascend a hill in company with my grand-

father, who has been dead some thirty years. I leave him for a moment to make sure of the road, and on returning he has disappeared and is nowhere to be found. As perceptions of external phenomena this train of experiences involves a tissue of absurdities; but one may find its counterpart in many a train of thought which takes place during waking life.

Dream experiences may contradict our knowledge of physics and other natural laws, as when we dream of walking on air. One dreams of reading in the paper an account of a football game and at the same time he is rushing down the field with the ball under his arm. In waking life this is paralleled when we read of an event and at the same time form images of what we read about. The difference is that in dreams we have no external data to compare with the ideational states, and the latter attain the vividness of perceptions. We dream of Africa and we find ourselves there. We dream of a dead friend and he stands before us.

Since in sleep many of the centers are cut off from one another, we are often unable to associate the given experience with our built-up store of memories. Thus we find nothing startling or unreal in seeing before us someone long dead. At times an incongruity may be noticed and may puzzle us, as when we discover one family living in a house which we know is occupied by another. In such cases a false memory may be constructed to explain the contradiction; we 'recall' that A rented or sold the house to B. These false memories are counterparts of the thoughts which arise when we seek to account for apparent contradictions in waking life. In waking life we say, "Did A rent or sell the house to B?" In dreams the thought takes on the character of a memory image. The sudden appearance and disappearance of objects and persons in dreams is an indication that the apparently perceptual states are thoughts; dream experiences 'behave' like ideas, not like external things. In every respect dreams

proceed in the same way as trains of thoughts, and not as trains of perceptions.

Since dream states are thoughts, and not voluntary acts, it is readily understood why honorable persons sometimes dream of committing dishonorable actions, such as lying, stealing, or killing. Everyone thinks of these acts, though in waking life we usually think of them as performed by someone else. In dreams, experience tends to a more subjective form. When we dream of the act of stabbing, the kinesthetic part of the experience is more vivid than in waking thoughts, and the mental state reproduces the central conditions of volition, without the motor activity. We picture *ourselves* as performing the act.

The Freudian psychology emphasizes the importance of our subconscious life in determining dreams. According to this view, in waking life certain thoughts which distress us or render us uncomfortable are banished from the focus of consciousness and even from the 'margin' as that term is generally understood. They still persist, however, in subordinate centers, and constitute an underlying part of mental life, called the *subconscious*. The subconscious part of our mental life inhibits motor impulses aroused by conscious states and sends out motor impulses of its own. According to Freud the activity of the subconscious self is shown in many of our defensive reactions, and in our endeavors to conceal our true personality from others; it is betrayed by certain unaccountable acts on our part, by slips of the tongue or pen, and by the phenomena which accompany hysteria. Dream life is interpreted by Freud as a conscious manifestation of the subconscious self; the subconscious rises to the level of conscious experience.

Our study of dream phenomena in this section indicates that they proceed in precisely the same way as other trains of ideas. The "marginal mental life," with its manifold associated connections, often determines the trend of thought in

waking life. It probably determines the flow of dream experiences to the same extent. But the facts do not seem to require the hypothesis of an organized subconscious personality in the Freudian sense in order to account for the phenomena of dream life.

Hypnosis and Hypnotic Suggestion. — Another special condition of nervous organization is *hypnosis*. In this state the sensory and motor paths are not entirely cut off as in sleep, but certain pathways become more resistant, while others are unusually open to connection with the centers. The physiological state of hypnosis includes several phases, such as catalepsy, lethargy (trance), and somnambulance.

Psychological interest attaches especially to the peculiar *suggestibility* which appears in hypnosis. Verbal stimuli become much more effective than in waking life. The hypnotized 'subject' is directed to perform an act and he does it unquestioningly. If told that he is in a lake he immediately begins to make swimming movements. If it is stated that a sheet of blank paper is a letter from a friend he starts to read it. Suggestion may induce anesthesia of one or more of the senses. The subject will not flinch when pricked by a needle or touched with a hot iron, if the proper command be given.

Hypnosis is characterized at times by hyperesthesia of one of the senses; the subject is able to distinguish one blank sheet from another when told that they are photographs of different people. The ordinary sense of proportion and fitness may be quite lacking in hypnosis, and one will unhesitatingly perform acts which ordinarily would be inhibited by the feeling of absurdity or fear of ridicule.

The mental state during hypnosis is a condition in which the thought-life is raised to the focus, and perceptions and other sensations become less vivid. The succession of mental states in hypnosis follows the laws of ideational suggestion rather than the perceptual laws; but the stream of thoughts is controlled by verbal stimuli received through the external

senses. These stimuli are communications; they are social in character.

Social suggestion is an important factor in normal life. To a certain extent everyone is influenced by the words and acts of those about him. But in normal life the individual's personality, molded by past experiences, inhibits to a large extent the effect of such suggestions. In hypnotic life these inhibitions are lacking, and the suggestions received from the hypnotizer govern the flow of experiences. Only when they conflict with the most fundamental principles of our moral life do they seem capable of arousing resistance.

Reasoning. — Reasoning, or *rational thinking*,[1] is a special variety of trains of thought. It is distinguished from ordinary successions in that it is based largely upon meanings and values.

Our thoughts and images depend upon the retention trace left in our neurons by past perceptual experiences. But external stimuli affect us in haphazard order, so that the succession of perceptions is often quite unsystematic. The casual relations among perceptual experiences tend to be reproduced in our trains of thought. Thus our ordinary trains of thought may bring into association objects or events which are not actually connected in nature. I think of the former head of Princeton, James McCosh, and I think of the king of England; associating the two thoughts together I think of James McCosh as King of England. There is no more neural difficulty in making this connection than in associating the thought of another head of Princeton, Woodrow Wilson, with the thought of the presidency of the United States. But in the latter case the thought train corresponds to objective facts, in the former case it does not.

Reasoning is a special form of ideational succession which follows the processes of nature, and hence if the first state in the series corresponds to objects or relations in the exter-

[1] *Thinking* involves a succession of *thoughts*.

nal environment the train will represent objective facts and relations or changes. For example, $27+14=41$ is rational thinking. If we think of fourteen dollars added to twenty-seven dollars we conclude that there will be forty-one dollars in the group. The final thought of the series tallies with external conditions because the mental train is based upon external relations. The same applies to sheep or beans or bottles or anything else. We may reason about *objects* such as mermaids or philosopher's stones which do not exist in the external environment; or we may reason about *relations* which we have not observed in nature, such as negative and imaginary numbers or curved space, provided they fit in with observed relations. On the other hand the association of relations which *contradict* external experience is not rational thinking. We can perfectly well think $27+14=39$; but this is not a rational train of thought — it contradicts all our experiences of relations in the external world.

The rational type of association has been built up through our dependence upon the external world for the satisfaction of our wants and desires.[1] The association $27+14=41$ tallies with our perceptual experiences time and time again; hence it has an advantage over the association $27+14=39$ or other alternatives, which occur casually and rarely, which have no counterpart in perceived relations, and which do not serve to satisfy our needs in practical situations.

The fundamental principles of mathematics and logic give rise to certain fundamental modes of rational association. These fundamental modes are illustrated in rational trains of the form

$$A=B \text{ and } B=C; \text{ hence, } A=C$$
$$A>B \text{ and } B>C; \text{ hence, } A>C$$

It is perfectly possible for us to form thought trains which flatly contradict these logical principles. We can think of

[1] These are mental *attitudes* which will be discussed in chapter xvii.

John as taller than Henry, and Henry as taller than William, and William as taller than John. But when we test this out with actual external relations we find that it fails to meet the test: the third member of the thought train does not correspond to external facts.

Another mode of rational thinking consists in following out in detail the steps in a series of events. In ordinary sequences of thought I think of going from New York to Chicago, and immediately after I may think of my arrival there. In rational thinking I first consider the manner of getting to Chicago, think of consulting the time-table, packing, driving to the station, purchasing my ticket, and boarding the train.

The psychological characteristic of rational trains of thought is the vividness of the meaning and value elements in its members. This differentiates *rational* from *casual* thinking. When I think rationally of going to Chicago, the image elements corresponding to actual external conditions are vivid; the idea is not merely the arbitrary *name* Chicago, but imagery of actual perceptual situations which I might experience in getting there. The image elements in thought which correspond to perception constitute its *meaning* factor (ch. xv). In the same way quantitative reasoning (mathematics) is due to the vividness of the *value* elements in thought. When I add up a column of figures by mere casual association the value elements are marginal, and I frequently reach discordant results. When the value elements are focal the result is uniformly the same and tallies with external relations.

In the mental life of subhuman animals perceptions and other sensory types of experience are predominant; the ideational side is rudimentary. Hence, their actions, instinctively determined, tend generally to harmonize with nature. It is only when thought life begins to be predominant that disparity arises to any extent between the environment and organized reception. When reasoning is in the first stages of development it results in a host of irrational

conclusions; these form the basis of superstition, magic, and mysticism. Gradually rational thinking becomes differentiated from casual thinking, and as a result the mental life of civilized man is vastly more in harmony with the external world than the mental life of his primitive ancestors.

Among civilized races irrational thinking persists in dream life. In dreams our trains of thought sometimes follow the rational pattern, but more frequently they belong to the casual type. The dreamer lacks perceptual checks and a background of memory, and is unable to harmonize his judgments with actual conditions of the environment.

In many types of mental disorder the irrational pattern predominates. Perceptual tests are present, but the central connections are out of gear; the normal relations of sensation to thought and memory are distorted. Hence, among the insane either the whole system of thinking is irrational; or in some cases a fine, well-balanced train of reasoning is utterly vitiated by a single irrational step which the subject is unable to rectify. A certain patient would be a successful contractor and builder if he did not spend most of his time in devising means to rid himself of the electricity with which he declares 'they' have filled his head.

In normal waking life the principles of reasoning are constantly used in our trains of thinking. We do not focalize these principles specifically, but our thoughts nevertheless follow one another in a rational manner. Occasionally in the midst of rational thinking a casual association slips in. When we are adding a column of figures our thoughts of 8 and 7 may be followed by 13; or in a chess game we may think of moving a certain piece and afterwards think of it as still occupying the former square. Such slips are common with everyone, but a careful thinker is likely to discover and correct the error by noting some inconsistency to which it leads.

The evolution of rational thinking (reasoning) is the most important step in the growth of adaptive behavior. It en-

ables us to anticipate occurrences in the environment and prepare for them. Non-rational thinking coöperates with it ordinarily. By combined rational and casual thinking we imagine situations more or less contrary to actual experience, and consider how we would act in such circumstances. The harmonizing of our actions with the conditions of the environment is brought about most effectively by this coöperation of the two types.

General Stream of Experiences. — The stream of experiences which make up mental life in its entirety includes data of every sort — perceptions, imagery, feelings, conations, emotions, sentiments, volitions, thoughts, and ideals. These follow one another in various ways. With the exception of perceptions and thoughts we rarely experience a long train of one single kind of mental state. Usually a feeling leads to some sort of expression, which transforms the feeling into a conation or an emotion. Conative experience leads to new perceptions or to thought. An emotion soon exhausts itself and gives place to some other type of experience; while a volition results in motor activity, which is followed by a brand-new set of external stimuli.

With respect to their mode of transformation mental states may be grouped into three classes: (1) those which depend mainly upon conditions outside the organism; (2) those which depend upon internal stimuli; (3) those which are equally dependent upon external and internal conditions.

Perceptions belong to the first class, thoughts to the second; the other types of mental states depend upon both external and internal conditions and consequently follow both sets of laws given above. An emotion may be modified by a change in the external surroundings, or it may be swept away or completely transformed by changes within our organism. Our fear during a storm at sea may be intensified by the sound of a crash; or it may be transformed into awe when we think of the tremendous power of the waves. Our voli-

tion to go to the library disappears when we reach our destination; it may disappear sooner if we remember that the building is closed.

Conscious mental life may be regarded as a succession of experiences of every sort, one leading to another of the same or of a different type. In the general vista of experience there may be long unbroken stretches of perceptions and long unbroken stretches of thought; between these, patches of other experiences are interspersed here and there.

In almost every individual, civilized or savage, perceptions are most frequent and occupy the dominant position. Among educated adults of civilized communities ideational experiences occupy a good second place. Among primitive peoples the emotional life occupies a higher rank than thought and imagery. The expressive life (conation, volition, language) generally holds the third place in civilized races, coming ahead of the emotions; among savages it may also stand third, ranking just below the emotions; at times it may even occupy the second place.

Our experience at any given instant is ordinarily complex — it may include several distinct components, such as perception, thought, and volition. Where this occurs one of the states is usually focal and the others marginal. In the course of time some of the coexisting states are weakened and others strengthened by external or internal conditions; certain focal states fade into the background and certain marginal states become focal. If I observe my focal experiences and ignore the rest, my mental life appears to be constantly changing from thought to perception, and back to thought again — even apart from the changes produced by new stimuli. When I think about writing this chapter my perception of surrounding objects is marginal; suddenly my eye falls upon a clock and I jump up and get my hat; then having set out to meet my appointment the train of thought is resumed. At first sight the train appears to have been broken

and then renewed. Close observation may show, however, that it was proceeding, at least marginally, during the second stage.

Reaction Time. — The duration of experiences has been measured approximately in cases where reaction takes place immediately. If a stimulus gives rise to perception, recognition, etc., and a definite response follows at once, the period beginning with the stimulation and ending with the movement is called the *reaction time.* The central portion of this period is found by subtracting the sensory and motor conduction time from the total duration. Since the rate of nerve conduction is not known exactly, the duration of the mental state is subject to a certain error of calculation. But we can compare perception time with recognition time and association time provided the same receptor and effector are used, since the conduction time is the same in such cases.

Reaction times are usually measured by a chronographic record of tuning fork vibrations, or by a chronoscope whose dial indicates 1000ths of a second (σ). When the stimulus is given the chronoscope is electrically started. The reaction is usually made by pressing a key which stops the chronoscope hands. With the chronograph the beginning and end of the reaction are marked on the record.

Visual reaction is found to be considerably longer than auditory or tactile — probably owing to a difference in the nature of the receptor processes. There is also a difference in reaction time according as the attention is fixed upon the stimulus (sensory reaction) or upon the movement (muscular reaction). While individuals differ considerably in their reaction time, numerous experiments indicate the following averages for simple perceptual reactions:

Stimulus	Sensory attention	Muscular attention
Light	290σ	180σ
Sound	225	120
Electric on skin	210	105

[From Titchener, Text-Book, p. 432.]

Titchener found in his own case that recognition of a color required 28σ longer than simple sensory visual reaction. Recognition time for a letter of the alphabet was 51σ and for a short word 45σ. These *relative* differences hold generally, though the *absolute* times vary; it requires less time to recognize a word of three letters than a single letter.

Many investigations have been made on other complex reactions, such as discriminating between sounds of different pitch, reacting with one finger for one sound (or color) and with a different finger for another, associating some idea with a stimulus word, etc. The association times of various sorts of relationships are shown in Table XVIII (p. 343).

Laws of the Succession of Experiences. — The rôle of various factors in determining the general flow of experience may be expressed in the following laws:

(1) The succession of experiences depends upon the *relative strength of the nerve impulses* which occur momentarily.

(2) The initial strength of any impulse depends primarily upon the *strength of stimulation.*

(3) The strength of an impulse is altered during its course by the momentary *metabolic condition* of the several synapses through which it passes; this metabolism varies with local or general fatigue, rest, attention, distraction, etc.

(4) The summation and distribution of impulses (subjectively observed as mental succession) depends primarily upon the *structural arrangement of the neurons* into a system, inherited from our parents and modified by growth, use, and injury.

(5) *Motor impulses generate new stimuli,* which may lead directly to new systemic or motor sensations and indirectly to new external sensations.

(6) The strength of ideational impulses in transforming or overcoming sensory impulses depends upon the *resistance of the retention set.*

By taking these several factors into account the trans-

formation of one experience into another may be explained in concrete instances. In many cases the transition is not abrupt, but consists in a marked increase of vividness on the part of some mental state already marginally present, accompanied by a decrease in vividness of the mental state which has hitherto been focal. The succession here is not so much a transformation as a readjustment of the relative strength of the several parts of the whole field of experience; it is commonly known as 'change of attention.'

The rôle of metabolic conditions (third law) may be tested by listening to a very faint sound — one which borders on the threshold of sensation. If we listen intently, with no disturbing stimuli of any sort, we hear the sound for a time, then lose it, then hear it again, etc. This phenomenon, generally called the 'fluctuation of attention,' indicates a rhythm in the physiological processes.

The part played by heredity is indicated in the fourth law, and the influence of the environment in the second law and the latter part of the fourth.

The last two laws indicate the rôle of the individual himself in controlling the succession of his own mental states. The fifth law shows how we initiate new experiences. The sixth emphasizes the importance of our past life and personality in directing our stream of mental states. Our mental background includes something more than the specific effects of this and that concrete past experience. Retention traces modify one another and this results in *general ideational modes* or tendencies which influence the course of experience. A general trace of this sort is called an *attitude*.

Collateral Reading:

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Vold, J. Mourley, Ueber den Traum.
Hacker, F., Systematische Traumbeobachtungen, *Arch. f. d. ges. Psychol.*, 1911, 21.
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Practical Exercises:

Analyze the succession of experiences in one of your dreams.

Examine the flow of experiences during the past ten minutes, and study the interaction between perceptions and thoughts in the series.

Sit with pencil and paper and note the first word seen in a book opened at random. Write down the first idea which it suggests, then the first idea suggested by this latter, and so on for a series of 15 or 20 successive associations. Class the associations according to type; examine for laws of recency, etc.

CHAPTER XVII

ATTITUDES

Permanent Mental Conditions. — As we have repeatedly noticed, the mental state at any given moment is determined not merely by present stimuli and present nerve impulses, but also by the ' set ' or traces which previous stimuli and impulses have left in the nerve substance. The traces of an individual's past mental life serve to modify specific sensory experiences and arouse ideational experiences. In addition to this they tend to produce *general modifications* in his mental organization which alter the tone of his mental life as a whole.

When a certain type of experience is constantly repeated, a change of set is brought about which affects many central neurons and tends to spread over other parts of the central nervous system. These changes in the general set of the central system temper the process of reception; they lead to the formation of certain general modes of receiving and integrating stimuli. In terms of the subjective mental life these general sets are called *attitudes*. A man's attitude toward any situation which confronts him is quite as important a factor in his mental life as the nature of the specific stimuli which enter into that situation.

The specific attitudes which develop during the course of life affect one another and result in the formation of general attitudes. These general attitudes constitute the various phases of the individual's *character*.[1]

In the same way the several phases of character become organized into the ' general character ' which permeates an

[1] The term *character* is sometimes used more broadly as a synonym for *personality;* it is also frequently restricted to a single type — *moral* character. There is justification, however, even in popular usage, for the intermediate definition adopted here.

individual's whole mental life. This summation of one's past is called *personality*.

Attitudes alter from time to time with the growth of experience; but changes of attitude proceed far more slowly than the changes of specific mental states. Similarly, character alters and develops as our attitudes change or as new attitudes arise, but at a much slower rate than the growth of attitudes. Personality, which depends upon the interworking of the several phases of our character, undergoes a still more gradual development and transformation; the growth of personality covers the entire period of our life-time.

1. Attitudes

Nature and Classes of Attitudes. — An attitude is due to repetition of neural processes of one and the same type. Each specific experience includes a focus of vivid consciousness and a margin or fringe of indistinct elements. The focal component is due to intense impulses which affect the given center. The marginal components are due to faint accompanying impulses. Since the mode of these faint components, insofar as it is not due to present sensory stimuli, is determined by the set of the neurons, our marginal consciousness reflects in great measure the permanent effects of past experiences. Our experiences take on a characteristic tinge due to this general set. In any given experience this permanent tinge constitutes our *attitude* toward specific stimuli or toward the entire situation which confronts us. The relation between the stimulus and attitude factors is illustrated by comparing the experiences of watching a bonfire and a destructive conflagration. The sensory stimuli may be substantially alike in the two cases, but our response is quite different. We assume entirely different emotional and motor attitudes.

Attitudes are classed according to the type of mental state which characterizes them. There are attitudes corresponding to each type of experience, but some types are more fully de-

veloped than others and play a more important part in mental life. The principal classes of human attitudes and their sensory origin are shown in Table XIX.

TABLE XIX. — HUMAN ATTITUDES

Attitude	*Mental Basis*
Primary:	
Interest	Perception, Ideation
Desire	Feeling
Attention	Conation
Secondary:	
Dispositions	Emotion, Sentiment
'Appreciation'	Thought
Social and Moral (Conscience)	Social Situations
'Proclivities'	Volition
Of Communication	Language
Of Rational Action	Ideals

a. Interest. — Interest is our mode of receiving perceptions of the external world and our attitude toward imagery or thought derived from external stimuli. The experiences which arouse interest are concerned principally with the relations of objects and events to one another and to ourselves. The child manifests interest in isolated experiences, that is, in the specific objects and events which are received through the external receptors. The adult is less interested in specific occurrences than in their changes, their differences, and similarities.

In the course of an individual's life-time he builds up a system of meanings and a scale of values. The development of certain meanings fosters his interest in the corresponding kinds of objects and events, and the scale of values regulates the degree of interest attaching to each. Interest serves to maintain an experience in the focus of consciousness. Lack of interest results in shifting the focus from one perceptual or ideational experience to another.

Professional baseball players have developed a high degree of interest in the situations involved in the game; the invet-

erate 'fan' acquires a similar interest through constant attendance. In either case the interest attitude is not itself a focal experience. The player and the fan are seldom aware of their interest, but they are vividly aware of each situation in the game and of each individual play. The interest attitude maintains the details of the game in the focus of consciousness; it inhibits the players from hearing the shouts of the spectators, and prevents the spectator from thinking about his business problems or leaving the field before the game is finished.

In visual perception interest is associated with the center of vision, while the data furnished by the periphery of the eye are generally but little noticed. By training one may acquire a capacity for observing out of the "corner of the eye" without moving the eyeball so as to center the objects observed. This is brought about by the attitude of interest toward peripheral parts of the retina.

Interest attaches not only to perceptions, but to images and thoughts which represent external situations and events. Interest in science attaches largely to thought experiences. The inventor's interest is aroused when he considers what device would produce the desired external result — even before he attempts to try it out. So far as we observe, there is no essential difference between these ideational attitudes and the perceptual attitudes. They are attitudes of the same type and are covered by the single term, interest. Moreover, interest attitudes differ in degree rather than in kind. The *quality* of interest is the same whatever the specific experience to which it attaches.

b. Desire. — Desire is the attitude which develops in connection with the systemic experiences, or feelings. It has two forms, corresponding to the affective modes of pleasantness and unpleasantness. Our attitude toward pleasant states is called *satisfaction*. In the case of unpleasant states the attitude is something more than the opposite of this —

dissatisfaction; it carries with it a picture of the removal of the unpleasantness or of its transformation into pleasantness. This attitude is called *want*, or need.

The satisfaction attitude is a less distinctive experience than want. The pleasantness of the experience itself is the dominant factor, and the attitude usually plays an unimportant part. But in states of unpleasantness the attitude of want tends to share the focus with the feeling of unpleasantness. While specific systemic ideas are rare, the *want attitude*, which has an ideational tinge, is a most important factor in mental life. Through instinctive and intelligent reactions the want attitude leads to motor expressions which tend to transform the unpleasant state into pleasantness. Our responses do not always yield stimuli which fulfill our needs. But the want attitude is generally followed by motor impulses of *some* sort, and as adjustment develops, the tendency to fulfillment is increased. The satisfaction attitude is more often quiescent.

c. Attention. — Attention denotes our kinesthetic attitude.[1] It is due to marginal kinesthetic elements which produce certain minor discharges in the outgoing motor nerves. These slight motor impulses are not sufficient to produce gross muscular contractions, but they adjust the muscular tension and serve to maintain or alter the focus of consciousness. When we fix the eye, clench the teeth, wrinkle the brow, etc., these motor adjustments assist in maintaining some present mental state as focal, or serve to focalize a marginal state.

In strenuous efforts of attention many different motor adjustments are involved and the impulses are frequently very intense. In thinking out a difficult problem we often draw long and deep breaths and maintain the muscles throughout the body in a state of rigid tension. These slight secondary motor discharges take the place of gross discharges through

[1] The term *attention* is used, it will be remembered, in a technical sense; see p. 141.

the ordinary motor channels, which would produce new and distracting stimuli, so that we are enabled to pursue unhindered a train of thought, the main nerve impulse passing from center to center in the brain for a long time.

Attention is not the focusing process itself. Focalization occurs as a result of attention. There are also cases of focusing which occur quite independent of attention and even in spite of the attention attitude. A loud sound may produce a focal auditory perception despite our every effort to attend to a train of thought or reasoning. This type of focalization is often called *involuntary attention.*

Relation of Attention to Interest and Desire. — In popular language *attention* and *interest* are used almost interchangeably. As a matter of fact attention is the motor attitude, while interest is based upon perception or ideational states which result from perceptual experiences. They are separate factors, though generally found together in one experience. Indeed in many experiences interest, attention, and desire are so united that it is difficult to distinguish them. We desire and attend to that which interests us; we become interested in and desirous of what we attend to; or we assume attention and interest toward that which we desire.

The three primary attitudes coöperate in complex experiences. They are often called *motives* of life,[1] since they serve to control and guide the succession of experiences. When they appear together they give a specific tone to our mental life which is termed *striving* when the motor component is active, and self-control or *repression* when it takes the form of inhibition.

d. Dispositions. — A disposition is an emotional attitude, or one in which emotion or sentiment is a leading factor. Emotional attitudes are the most fundamental of all the secondary types. They arise through the frequent repetition of

[1] Ideals are motives in the same sense, but they are more definite mental states. See ch. xv.

similar emotions, which leave a permanent trace in the nervous system.

In civilized man there is almost universally a social tendency to suppress emotional expression, and this partial suppression reduces the emotional state to a disposition. The emotion of *joy* simmers down into an inground *cheerful* disposition; the emotion of *anger* leads to a *hostile* disposition; the emotion of *suspicion* to a *distrustful* disposition. In fact, nearly every class of emotion gives rise to a corresponding attitude or disposition, as is seen by comparing Table XX with the list of emotions in Table XVI (p. 299).[1] In some cases the social suppression of emotion leads to an attitude of a somewhat contrary sort, as in the case of courage, which seems to have developed from the emotion of fear.

Only the leading types are included in the Table. There are a great many variations of these types — some of them so common as to carry familiar names. We distinguish between the overbearing, the superior, the condescending, and the pompous attitudes — all variations of the arrogant type. If one is accustomed to study human nature he will find no difficulty in applying each of these designations to some of his acquaintances.

The variety of forms assumed by emotional attitudes is in striking contrast with the uniformity of the interest phenomenon. The other secondary attitudes show considerable variety, though far less than the dispositions.

[1] Table XX is based upon an examination of terms in common use (language psychology), checked up by self-observation. Two difficulties appear in testing the list: (1) Popular psychology does not distinguish clearly between emotions and dispositions; the same words are often applied indiscriminately to both—e.g., cordiality, friendliness. (2) The same term is applied by different writers or speakers to somewhat different dispositions: *sullen* means one attitude to one observer, another to another. Any such table can only be treated as tentative at the present stage of investigation; a satisfactory list of emotions and dispositions seems to require quantitative determination of the various glandular and metabolic activities which accompany them; we are not yet in a position to make these determinations.

TABLE XX. — HUMAN DISPOSITIONS

1. *Expressive*

Attitude	*Emotion*
Cheerful	Joy
Despondent	Grief
Dazed	Shock
Frivolous	Mirth
Zealous	Ecstasy
Erratic	Restiveness
Romantic	Exuberance
Devout	Wonder

2. *Reproductive*

Attitude	*Emotion*
Affectionate	Love
Lascivious	Lust
Jealous	Jealousy
Motherly	Tenderness.

3. *Defensive*

Attitude	*Emotion*
Cowardly	Fear
Courageous	"
Aversion	Disgust
Cautious	Timidity
Reserved	Shame
Servile	Awe

4. *Aggressive*

Attitude	*Emotion*
Hostile	Anger
Vindictive	Hatred
Malicious	Envy
Ambitious	Pride
Arrogant	"
Bold	Exultation

5. *Social*

Attitude	*Emotion*
Devoted	Affection
Friendly	Cordiality
Compassionate	Pity
Attachment	Gratitude
Loyal	Admiration
Antagonistic	Detestation
Sullen	Revenge
Distrustful	Suspicion
Supercilious	Scorn

6. *Instinctive and Sentimental*

Attitude	*Basis*
Miserly (Avaricious)	Acquiring instinct
Orderly	Cleanliness
Nomadic	Wandering instinct
Credulous	Belief
Skeptical	Disbelief
Perplexed	Doubt
Biased	Belief and Disbelief

Popular psychology distinguishes between a *disposition*, which is a more or less permanent attitude, and a *mood*, which is liable to frequent fluctuation. The distinction seems valid, but it is of social rather than psychological importance. Our emotional attitudes become established by slow degrees, and the border line between a passing mood and an inground disposition is indefinite.

Sentimental attitudes are closely related to emotional attitudes; this probably accounts for the popular confusion be-

tween the mental states which generate them. Doubt gives rise to a *perplexed* attitude, while a mingling of strong belief with strong disbelief produces a *biased* or *prejudiced* disposition. Certain attitudes are apparently derived from instincts directly, with no emotional intermediary; as for instance the *avaricious* and *orderly* dispositions.

The wide reach of emotional attitudes is observed in the opinions and judgments expressed in every-day life. They color even biographical estimates and histories — particularly those written nearly contemporaneously with the times they portray.[1]

Most of our dispositions, like our emotions, are imperfectly adjusted to the conditions of civilized life. If we test our emotional attitudes (or better those of others) by social experience, we observe that the emotional component generally hampers the intercourse of man with man. The servile disposition is as disconcerting as the arrogant. The exceptions (loyal, compassionate, etc.) are precisely those dispositions which promote mutual coöperation and which therefore run parallel with the social attitude of our ideal life.

[1] The following fictitious illustration contains contrasted statements by two opposing parties. They embody the same facts. The sole difference is in the attitude, marked by changes in the emotional words:

The Judean government has permitted the criminal machinations of various societies and associations directed against the Roman dominion and has tolerated unrestrained language on the part of its citizens, glorification of the perpetrators of outrages, and participation of Judean officers and functionaries in subversive agitation against Roman authority. It has permitted an unwholesome propaganda in public instruction. In short it has permitted all manifestations of a nature to incite the Judean population to hatred of the Roman state and contempt of its institutions.

The Judean government has fostered the patriotic activities of various societies and associations directed against the Roman usurpation and has sanctioned outspoken expression on the part of its citizens, glorification of the heroic resisters of oppression, and participation of Judean officers and functionaries in agitation for the overthrow of tyranny. It has fostered a healthy propaganda in public instruction. In short it has fostered all manifestations of a nature to awaken the Judean population to hatred of the Roman state and reprobation of its institutions.

Since our dispositions are of systemic origin they are more subject to central control than phenomena of external origin. But they are less under control than kinesthetic phenomena. From the pedagogic standpoint the early training of emotions and dispositions seems even more important than the perfection of motor habits.

e. Other Secondary Attitudes.—The most important developments of attitude in connection with the higher secondary states are found in the sphere of thought and conduct.

Attitudes of thought (*appreciation* [1]) develop in a variety of different directions. Certain thought attitudes arise from sentiments when the feeling component is reduced to a minimum. One of the most important attitudes in the higher mental life of man is the interrogative or *problem* attitude, which is closely related to doubt, with the ideational factor emphasized. This attitude is not only experienced when we put specific questions to others or set ourselves to solve a problem, but it furnishes the basis for scientific investigation and rational thinking generally.

The leading types of thought attitudes are shown in Table XXI (1). The *interpretive* and *evaluative* attitudes permeate our perceptual life as well as our thoughts. We become trained to observe differences in kind and quantitative differences among the objects which we perceive. An interpretive attitude toward thought is cultivated by modern education. Writers learn to appreciate subtle distinctions in the meaning of words. Even the average reader acquires an attitude toward individual words. James speaks of the feeling which attaches to such minor words as *and*, *if*, *but*, and *by*.[2] These are really instances of the appreciative attitude, which leads us to interpret or evaluate the relations of words in a

[1] Strictly speaking the term *appreciation* applies only to the interpretive attitude and those that follow in the table.

[2] Psychology, p. 162. James applies the term *feeling* to any indefinite mental state or attitude.

sentence as well as relations of objects. Rational thought develops certain attitudes of consecutive thinking, such as the *analytic*, *constructive*, and *critical*.

TABLE XXI.—HIGHER HUMAN ATTITUDES

1. *Attitudes of Thought* (*'Appreciation'*)

Attitude	*Basis*
Interrogative (Problem attitude)	Doubt (feeling marginal)
Impartial	Belief (" ")
Retrospective	Memory coefficient focal
Anticipatory	Purpose (volition marginal)
Desultory	Associative thought
Naïve	" "
Interpretive	Meaning
Evaluative	Value
Esthetic appreciation	Esthetic sentiment (feeling marginal)
Rational, Logical	Rational thought
Analytic	" "
Synthetic, Constructive	" "
Critical	" "

2. *Social and Moral Attitudes* (*Conscience*)

Conciliatory, Coöperative
Contrary, Competitive
Accusatory, Condemning
Laudatory, Approving
Judicial

Self-centered, Self-satisfied
Altruistic
Penitent
Suppliant
Forgiving
Prudish
Irresponsible
Superstitious (fetish and tabu)
Duty-bound (of moral obligation)

3. *Other Secondary Attitudes*

(a) *Motor Attitudes* (*'Proclivities'*):
Persevering, Obstinate
Vacillating

(b) *Language Attitudes:*
Receptive
Expressive
Voluble
Reticent

(c) *Ideal Attitudes:*
Idealistic
Practical
Sensual
Scientific
Artistic

In our relations to other men and to society at large a number of important social attitudes have arisen (Table XXI, 2).

A satisfactory classification of these is difficult, because they shade from emotional or volitional experiences into the sphere of conduct by gradual degrees. Thus the fault-finding (*reproachful*) attitude contains a large element of emotion but is tinged with a ' sense ' of obligation toward society; the *inculpatory* attitude of a public prosecutor, on the other hand, is ethical with scarcely any emotional tinge. Midway between these is the *accusatory* attitude so frequently noticed in modern political and community life.

The term *conscience* is commonly applied to attitudes of conduct (moral attitudes). In general usage it has a decided emotional tinge; and this use is historically justified, since the emotions have been a potent factor in developing our social ideals and conduct. But the notion may be extended to such unemotional phenomena as the *judicial* attitude and the " sense of moral obligation " (the *duty-bound* attitude).

It should be recognized by psychologists that while the social and moral attitudes *as experiences* evolve in much the same way in all races, the situations which evoke them vary greatly in different communities and stages of civilization. Or to put it the other way around, the same act or the same objective situation may yield very different attitudes in various races and culture-stages.

Among the ancient Romans it was the accepted custom to expose to death new-born children if they were deformed or weak. The same custom holds today among the Eskimos. In other societies, such as our own, these weaklings are especially cared for and protected. In many communities the child is regarded as the slave of his parents, who do not recognize any obligation toward their offspring except to feed and clothe them. In other communities there is a recognized obligation on the part of the parents to educate their children and fit them for their life-work. Whether the attitude of obligation is assumed in a given situation depends upon the traditional customs of the people.

The sexual and marital code is subject to similar variation. Among uncivilized tribes some insist upon marriage within the clan; others insist quite as strongly upon exogamy. In certain communities polygamy prevails, while in most modern civilized communities the traditional social rule is monogamy. From the standpoint of systematic ethics these differences are of fundamental importance. The science of ethics seeks to determine which code is higher and better. But psychology is interested in *duty* chiefly as a datum of experience. We are concerned with the *attitude* — not with the social and moral worth of the act or situation in the evolutionary scale.

An attitude is generally a marginal component of the present mental state. This is as true of moral attitudes as of other types. When we act in a friendly way, speak the truth, or refrain from hurting another's feelings, we are usually not distinctly aware that a moral attitude is involved. But on occasion the moral experience becomes focal, more especially when our conduct is at variance with a recognized moral code. The mental state thus aroused is a moral *ideal* rather than an attitude. In such cases it is the feeling components that are apt to be especially focalized. In the popular conception of conscience this predominance of the affective side is emphasized. The well-known 'Puritan conscience' of the Anglo-Saxon race belongs to this type.

A clearer conception of the duty attitude and other moral and social attitudes is attained if we realize (1) that in normal circumstances they operate as readily when they are only marginal as when they are focalized; (2) that under civilized conditions the affective component — the 'feeling' part of the attitude — is more often a hindrance than a help to the adjustment of social relations.

The remaining classes of mental states furnish less prominent attitudes The use of language results in *receptive* and *expressive* attitudes and in the *voluble* and *reticent* types. Volition develops the *persevering* attitude, with its variant,

the *obstinate;* in the other direction it leads to the *vacillating* attitude. We may call these motor attitudes *proclivities.* Ideals give rise to the *idealistic* attitude, the *practical, sensual,* and other types. (Table XXI, 3.)

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Practical Exercises:

Compare the stimulus effect and your attitude in reading a novel, in watching a ball game, in discussing some question with a friend.

Analyze the attitude of pique ('being peeved') in yourself and others, including its characteristic manifestations; also the jealous and devout attitudes.

Examine some important congressional or legislative debate; determine to what extent the attitude of participants was conciliatory, accusatory, and judicial.

CHAPTER XVIII

CHARACTER AND PERSONALITY

2. Character

Nature of Character. — Character is the *general rating* of an individual in any specific phase of mental life. It denotes the degree and trend of his mental development in that particular sphere. In popular language the term is usually limited to a man's moral standing or rating. In psychology it has a broader application; it includes also his rating in the perceptual and ideational life, in the hedonic life, and in the motor life. The same man may be rated as malevolent, keen, sanguine, and energetic. These represent different phases of his character. Each phase of character may embrace a number of independent *traits*.

As the child grows toward maturity the same types of experience are constantly repeated with minor variations. With each repetition his attitude becomes more clear-cut and definite. Many such attitudes develop and modify one another. The interworking of various attitudes in each sphere of experience results in building up our general attitude, or *character*. Our character forms the background of our subjective mental life, and the character of other individuals may be observed objectively through their behavior.

One's specific attitude in any complex situation is determined by the general attitudes which have been built up in his past. A man's character — that is, his general attitude toward the environment at large, toward others, toward himself, and toward 'life' — is indicated by the trend of his concrete actions. Given a sufficient number of specific responses, it is possible for an observer to "size a man up" pretty accurately.

Strictly speaking, a man's character is not the rating which his fellows actually give him;[1] for such ratings are liable to error. Character is the rating which the individual would receive if one could appraise him correctly.

The principal lines of character development correspond to the fundamental types of sensation (internal, external, kinesthetic), with a fourth which arises from social relations. These phases of character are called

Temperament
Intellectuality
Skill
Morality

a. Temperament. — Temperament is the phase of character based upon an individual's hedonic attitudes; it expresses the development of his systemic life. We rate a man's hedonic standing quite apart from his intellectual or moral standing.

The older psychology recognized four kinds of temperament, the choleric, melancholic, sanguine, and phlegmatic. This classification was based upon a doctrine of internal secretions which though in the main erroneous contained a germ of truth.

Temperament is possibly correlated with the modes of heart action. The heart-beat may be strong or weak, and it may be rapid or slow. Combining these pairs we get four varieties of temperament which correspond to the classic types. The *sanguine* temperament represents strong and slow activity, the *melancholic* weak and rapid, the *choleric* strong and rapid, and the *phlegmatic* weak and slow.[2]

An objection to the four-fold division is that it does not take account of the positive and negative phases which form the differential basis of hedonic phenomena. The

[1] This tentative rating is a man's *reputation*.

[2] In the classical scheme sanguine = rapid-weak, melancholic = slow-strong.

optimist and the pessimist would both belong to the sanguine type.

A more exact classification of temperaments is based upon both the mode of activity and the quality of hedonic tone. The former has two phases, active and passive; the latter three phases, pleasant, unpleasant, and indifferent. Combining these two groups of characteristics we obtain the six varieties of temperament shown in Table XXII.

TABLE XXII. — CLASSIFICATION OF TEMPERAMENTS

Mode of Activity	*Hedonic Tone*	*Temperament*
Active	Pleasant	Sanguine
	Unpleasant	Choleric
	Indifferent	Mercurial
Passive	Pleasant	Jovial
	Unpleasant	Melancholic or Saturnine
	Indifferent	Phlegmatic

b. Intellectuality. — Intellectuality or intellect[1] is an individual's general rating on the ideational side. Broadly speaking, this includes the development of attitudes derived from perceptions and imagery as well as those derived from the higher secondary processes of thought, judgment, and reasoning.

Perception and imagination are generally less important factors in the individual's intellectual character than memory, judgment, and reasoning, though at times they enter as prominent factors. The man whose perceptions are clear has usually a better developed memory than his fellows; a highly developed imagination serves the inventor and artist better than a corresponding growth of judgment and reasoning.

The growth of intellect depends more upon 'social atmosphere' and training than on the variety and nature of general external stimuli. A person like Helen Keller, de-

[1] Often called intelligence; this term is used technically in a slightly different sense (ch. vii).

prived of the two most important sources of information, sight and hearing, may through careful education attain as high an intellectual level as one provided with all the usual avenues of information. But intellect depends upon inherited nerve structure even more than on training or other environmental influences. This is demonstrated when we compare the intellectual rating of the dog or the worm with that of low-grade human individuals.

Intellectual development proceeds in two distinct directions, which correspond in a figurative way to the spatial dimensions of *breadth* and *height*. Breadth denotes the *number* of different traits which the individual has developed; height means the *amount* of growth in each independent attainment. The breadth of our intellect depends essentially upon the complexity of our inherited nerve structure, while its height depends more largely upon education.

Both breadth and height must be taken into account in rating an individual. For example, there are instances of mathematical prodigies and memory geniuses who fail to reach the average intellectual level in other respects. On the other hand there are men possessed of small snatches of knowledge and mental capacity in many directions who fail to measure up to the average in any one particular. A man of high-grade intellect is one whose attainments are both broad and highly developed.

Various attempts have been made to measure intellectual attainment. So far they have met with only partial success. The difficulty has been to distinguish the independent phases of intellect and to estimate their relative importance. A most important step in this direction is the scale devised by Binet and Simon for measuring the mental growth of children. This scale consists of a large number of tests involving various sorts of mental states (perception, memory, imagery, and reasoning), and so graded that the child's success in performing the tests successfully, measured and averaged, will indi-

cate his general intellectual level. For example, the growth of memory is tested by ability to repeat sentences of various lengths and series of numbers of three, four, five, and more figures. Rational thought is tested by making statements containing some absurdity, which the child is asked to point out.

The success of the Binet Scale as a measure of intellect is due to the fact that the intellectual development of children is relatively simple; they have not yet developed a great variety of complex mental traits. By examining all the children in a large school and comparing those of each age, it is found that 50% of the 10-year-old children succeed in a certain number of these tests. This is taken as the measure of the average level of intellect at that age. The same procedure is used in determining the standard for 9 years, etc. Those children of 10 years who only attain the 9-year standard are said to be 1 year backward; their 'mental age' is 9 years. And so for other ages.

In attempting to apply mental tests to adults a difficulty arises from the great differences in *breadth* of development. A man may be highly developed along certain lines and deficient in others. It has not yet been determined satisfactorily how to compare these different attainments with one another so as to represent fairly the individual's mental level. Recently a set of mental tests for adults has been devised for use in the United States Army which promises good *general* results; but this is only a beginning.

A mental scale for adults, to be complete, should include separate tests for each kind of intellectual state which develops independently of others. It should distinguish also between those traits which have been developed by special training or schooling, and those which grow up under the ordinary influences of social environment. The latter seem to deserve a higher rating than the former. Mere scholarship and information do not signify so high a degree of intellectual

attainment as the less cultivable processes which underlie them.

In applying mental tests special care should be taken that the results are truly representative. If the individual tested has been 'coached,' his answer to a question supposed to involve reasoning may be really a feat of memory. A phonograph, supplied with the proper record, might yield results indicating a superlative degree of intellectuality according to the scale. Such a result indicates merely the intellect of the individual who prepared the record. Unless due care is taken in giving a mental test (or a college examination for that matter), the results may indicate the intellect of the 'coach' — not the mental level of the testee.

In the mental life of man intellect is a far more important phase of character than temperament. In our relations with the social environment it is useful to cultivate special temperamental traits and inhibit others; but the development of intellectuality contributes more to success and happiness in life than the cultivation of temperamental character.

c. Skill. — Skill is the motor character of the individual. It means the rating of his development on the kinesthetic side. Like intellectuality, the growth of skill depends upon environment and inheritance. The environmental influences include general physical environment, social suggestion, and special training. The inherited factors include the individual's complex nervous system and effector organs.

Nerve structure is far more important than elaborate motile organs in developing skill. The presence of muscles is essential to movement; but the coördination and fine adjustment of movements is controlled by the central nervous system. A study of handwriting will demonstrate this. First write your name in the ordinary way; then write it in very small letters, using only finger-movements; then keep your fingers rigid and use only the wrist; finally write your name in large letters on the blackboard, using only arm movements.

Although the muscles involved are different in each case, there is found to be a general similarity between the several results;[1] the individuality of a man's handwriting is due to characteristics of the impulses from the brain centers, not to the constitution of the muscles.

Skill, like intellectuality, develops in two dimensions, breadth and height. Breadth is measured by the number of independent motor acts which the individual can perform. Height is the degree of perfection in performance.

The great *breadth* which characterizes the motor development of civilized man will be realized if we attempt to list the acts of every-day life. The catalogue would include such varied acts as eating, dressing, writing, drawing, orating, needle-threading and sewing, building a house, juggling balls, and a host of other performances. In comparing the motor character of individuals, and more especially in rating the comparative development of various races, breadth of skill is an important factor to consider.

On the other hand, *height* — the individual's degree of success in performing any specific type of activity — furnishes a more adequate index of skill. In determining height of motor attainment two separate factors must usually be measured: temporal *speed* and spatial *accuracy*. In tests of skill we seek to determine (1) the number of errors or amount of inaccuracy, and (2) the time which it takes to perform the given act.

It is often difficult to estimate the relative value that should be attached to these factors. In certain kinds of work accuracy (precision) is of far greater importance than speed; in other cases the opposite is true. A telescope lens, for example, must be ground to the utmost degree of accuracy, regardless of time expended. A ready-made shirt or shirt-waist on the other hand must be finished quickly in order to

[1] A similarity is also reported between the left-hand writing of those who have lost their right arm, and their former right-hand script.

reduce the cost of production; irregularities in the cutting are taken as a matter of course.

How far such economic valuations should be carried over into psychological testing is problematic; but some criterion of the relative importance of the two factors is essential. Occasionally conditions may be so arranged that speed and accuracy are reduced to a single variable. In a certain tapping test the individual is required to insert a plug into a series of holes in succession, as rapidly as possible; each insertion produces an electric contact. If the testee fails to strike the proper hole at first he must correct the error before proceeding to the next hole. Here the space error is transformed into a time error; the inaccuracy factor is eliminated entirely and speed is the only variable.

A scale of skillfulness, like the scale of intellectuality, should include a great variety of typical, independent acts, if it is to indicate breadth as well as height of attainment. Up to the present, the construction of a measuring scale for skill has not progressed so far as the scale for intellect. The importance of intellect seems to have been somewhat over-emphasized in modern civilization. We are beginning to recognize today that skill is an essential phase of human character.

d. Morality. — This is the phase of character concerned with the individual's relations to his fellows. Morality depends upon our social existence. A man living like Robinson Crusoe in solitude, with no other human beings about him, has practically no moral duties. Even such an imaginary case, however, needs qualification: a castaway lives in the hope of rescue and acts with reference to his possible rescuers; he expects at least that someone will discover his remains and he orders his life accordingly. For most men social experiences play a dominating rôle in mental life. In civilized communities moral character is quite as important a phase of character as any of those which depend more directly upon

sensory data. The popular tendency, in fact, is to magnify it at the expense of all other phases.[1]

The development of moral character proceeds in the direction of height rather than breadth. Our range of social relationships expands slowly. Family relations include a few different types: filial, parental, and marital. Community life includes the general relationship of man to man and a number of specific relationships: friendship, business dealings, community interests, etc. Beyond this lie a group of broader social relations — to our country, our race, and mankind.

Far more significant than the range of social relations is the degree to which an individual enters into these relations. Height of moral character is measured by the individual's success in acting so as to benefit his fellows and avoid doing them injury.

Morality is rated largely in terms of motor expression, or *conduct*. A man's moral character is measured not so much by his feelings and thoughts as by what he does or neglects to do. Yet in a scientific rating of moral development all three sensory sides of mental life are to be considered. Sympathetic or antipathetic emotions, social or anti-social thoughts, are potent factors in determining our actions toward our fellow men. A scale of morality, if one could be devised, would take into account the individual's social thoughts and feelings as well as his actions.

Moral character is quite as susceptible to directive training as intellectuality and skill. While a child gains many of his

[1] The study of moral character is usually assigned to a distinct branch of science called *ethics*, which occupies the border line between psychology and sociology. A distinction is often made between social psychology and ethics in the narrower sense. Social psychology investigates how men *customarily act* in relation to one another; ethics is limited to determination of the principles according to which they *ought to act*. It would seem more scientific to treat these two phases together; for the scientist determines how men *ought* to act only as a result of determining how they *do* act.

fundamental principles of morality by suggestion from the 'unorganized' social environment, the organized moral education which he receives in the home, the school, and the church are of the utmost importance in enabling him to apply these principles correctly.

3. Personality

The Self. — Personality is the *general rating* of an individual. It embraces all the various phases of one's character — temperament, intellectuality, skill, and morality. Personality sums up the total mental constitution of a human being at any stage of his development; in other words, it is the man's 'general character.'

We may distinguish between *personality* and *individuality.* The study of a man's personality is an attempt to measure or rate him according to the standards which are common to human beings generally. The study of his individuality is an attempt to bring out the differential characteristics which mark him off from others. If we investigate a man's handwriting as an index to his temperament, intellectuality, and skill, we are studying this particular man's personality. On the other hand, if our object is merely to note the idiosyncrasies of his script, the study becomes one of individuality. The same is true of any similar investigation.

As a psychological term, personality denotes the man's combined rating in the several phases of mental life, while individuality is the sum total of his variations from the average. Personality and individuality, taken together, constitute the *self.*

Psychology as a science is not especially interested in individual differences,[1] except so far as they may be traced to the influence of heredity, organic defects, specific training, social environment and occupation, and other general factors. To

[1] Applied psychology, which is an art rather than a science, is almost wholly interested in these differences.

this extent they are investigated in the branch called *individual psychology.* General psychology is the investigation of the common features of mental life, which are summed up in personality.

The self, or mind, or personality, is not to be regarded as an abstract being, an entity distinct from the specific phenomena of mental life.[1] Man's self or personality is the sum total of his specific experiences insofar as they represent the results of organization. Each new experience modifies our personality. It is not merely an accretion to the sum of our mental data, but it alters our attitude toward the external world and makes a permanent impression, small or great, upon our general character. This permanent modification of the individual through experience is characteristic of all the higher organic species, but preëminently of man.

So far the attempts at a scientific measurement of human personality have met with little success. Most of the essays and books on personality are written by amateur psychologists, who have no appreciation of the real problems involved. They emphasize certain striking *individual* features, or deal merely with a few distinctive traits of character. The trained psychologist is apt to avoid the problem altogether.

The reason for this is plain. Measurement of personality involves determination of the relative importance of the several distinct phases of character. In a general scale of human 'mentality' what proportion should be allowed to intellect? How much should temperament, skill, and morality count? Where such disparate factors are concerned the only satisfactory criterion, apparently, is the amount which each factor contributes toward the adaptation of our active processes to the conditions of our environment. It is readily seen that intellect is a highly important factor in promoting adaptation, and that temperamental growth is detrimental to smooth adjustment unless subjected to careful control by training. Up

[1] See Appendix, "Personification of Natural Phenomena," p. 433.

to the present psychologists have not advanced very far toward a quantitative expression of the relations between the several factors.[1]

Personal Identity and Multiple Personality. — In most human beings the mental states are organized into one single group and one continuous chain of experiences. The greater part of one's past experiences admit of being brought into relation with the present if the proper neural connections are made. My conscious life stretches back as far as I can remember, and every event which I recall is felt to belong to one and the same " myself." My present thoughts and feelings and activities, too, are tinged with a certain scarcely describable element which may be called the " sense of ownership." Sully[2] attributes this component to the vague (marginal) memory background of past experience which enters into the present mental state.

The 'me' component in memory experiences and the 'mine' component in new present experiences, taken together, constitute the experience of *personal identity*. This corresponds to a fact of mental life — that ordinarily the whole mass of an individual's experiences actually belong to one continuous series; that his mental life, though complex, is a *unity*.

In certain conditions this unity of self is broken. Groups of experiences may be dissociated from the general mass and become organized into a more or less definite personality of their own. This occurs most noticeably in functional derangements of the central nervous system, producing conditions known as hysteria. But similar phenomena may be observed in normal life.

'Split off' mental states occur separately as subconscious

[1] It should also be remembered that we have as yet made little headway toward explaining the *very complex* phenomena which enter into personality in terms of neural operations

[2] Illusions, p. 252.

experiences (ch. viii), though it is difficult to detect them unless they are well organized into distinct personalities. Many of our habitual acts, which to the performer appear unconscious, are most probably part of subordinate or subconscious personalities.

When one is able to perform two separate acts at once, such as cutting his food and planning a lecture, or knitting and talking, the two acts probably belong to separate mental organizations or personalities. Individuals susceptible to trance or hypnosis may be engaged in conversation and at the same time may write 'automatically' on some entirely different topic. In most cases of this sort, and in the dissociated states of hysteria, one of the personalities is subordinate to the other. The data from the minor self may be brought into relation with the major self, as when the lecture-planning self takes charge of the feeding operation, or the talking self turns attention to the knitting. These are typical cases of subordinate consciousness, or *secondary personality.*

There are occasionally pathological instances where the secondary personality becomes so completely organized as to constitute a separate self. The patient leads two distinct lives. Either there is in one state no memory of the experiences and doings in the other state; or state *A* may be remembered in state *B*, but not the reverse. The temperament and other phases of character may be quite different in one personality from the other. In Janet's historic case,[1] Léonie 1 was serious, slow, and timid; Léonie 2 was gay and restless. In such instances the secondary self has developed into a second primary self. This phenomenon is called co-consciousness or *dual personality.*

There is something fascinating to most of us in the study of these unusual phenomena. The casual observer regards them as weird and uncanny — perhaps as demon-possession

[1] *Rev. philos.*, 1888, 25, p. 260 (quoted by James). See Pierre Janet, Automatisme psychologique, pp. 132–133, 490–491.

or manifestations of a mysterious spirit-world. To the student of psychology all these instances, whether of secondary personality or of dual personality, serve rather to emphasize the general unity of the self. Multiple personality is the exception. For the most part our experiences are all woven together and 'organized' into a single personality: *myself*.

Self-Consciousness. — Our notion of self (the *self-notion*) is the focalized experience which arises in connection with this unity of personality. It develops from certain sensory experiences. Even in early life the child perceives his body through the external senses, and to this experience is attached a mass of organized systemic and kinesthetic sensations. Our feelings have a common tinge; our conative states are closely related together. The complex experience formed by the integration of all the sensory and imagery components which refer to the child's own body and its activities constitute his *self-perception* or *self-feeling*.

When thought and language develop the self-feeling is integrated into a thought, to which a name is attached. In the earlier stages this is not so much a self-notion as an object-notion. The child calls himself 'Baby,' or uses his own name: "Jack is hungry"; "Show it to Baby." His own personality stands on the same footing as that of other human beings. This first step may be called the *objective* stage of the self-experience.[1]

When personal pronouns come to be used the notion of self is sharply differentiated from the general notion of 'human beings.' This second step is the *subjective* stage; the child comes to recognize the peculiar relation of his own body and its activities to his conscious experiences.

The true self-notion dates from this stage. It develops constantly throughout life, especially among civilized and reflective beings. We 'read' a personality with systemic

[1] Baldwin calls it the *projective* stage. Soc. and Eth. Interp. (4th ed.), p. 13.

and kinesthetic experiences like our own into other human beings, and even into lower animals and inanimate objects. This *ejection* of our self-experiences into others is sometimes considered a third stage in the growth of the self-notion.

The notion of self is usually called *self-consciousness.* The term self-consciousness is sometimes limited to the reflective or focalized thought of self, when we attend to the specific characters of the self-experience. The distinction between self-consciousness as an attitude and the focalized self-experience is emphasized in philosophical inquiries, but it is of no special moment in psychology. It is merely one phase of the distinction between naïve and scientific observation of phenomena which was pointed out in an earlier chapter. We may distinguish in just the same way between every-day perception of an object and critical examination of this perceptual experience, as between ordinary and reflective observation of self.

Personality is the final step in the synthesis of experiences. It completes our survey of the central side of mental life.

Summary of Chapters XVI to XVIII. — In preceding chapters (xii-xv) we discussed the various types of central states which occur in mental life. But mental life is not a mere grouping of states at a given moment. It consists in a constant change and *succession* of states.

Two distinct types of succession were noted, with quite different principles of change. In one type (the perceptual) the chief cause of change is the activity of the environment; here the primary source of the succession is the outer world, though the stream is modified by various internal factors. In the second type (thought-trains) the chief cause of change is the ramified connections of the central neurons and the retention phenomenon; the primary source of the succession in this case lies within the nervous system.

The general succession of experiences is brought about by

a combination of both sets of factors, external stimuli and intra-organic conditions. In other words, the stream of mental life is molded in part by our present environment, partly by our neural constitution; the latter is determined in part by heredity and partly by our past experiences (ch. xvi).

The succession of mental states results in the formation of more or less permanent mental conditions. These constitute our *attitudes*, which appear in every phase of mental life (ch. xvii).

Attitudes consolidate along the main lines of mental development, forming the several phases of *character* — temperament, intellect, skill, and morality. A man's character in each of these phases denotes the variety and degree of his development on that specific side of mental life.

Personality is the sum total of character. It denotes the variety and degree of man's mental development taken as a whole. *Individuality* denotes his specific and peculiar development in any direction, which marks him off from his fellows. Personality and individuality, taken together, constitute the *self* (ch. xviii).

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Titchener, E. B., Text-Book of Psychology, secs. 135–137, 148.
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Prince, M., Dissociation of a Personality.
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PRACTICAL EXERCISES:

Study the different phases of character of some former close friend.

Analyze your temperament, and compare it with that of some intimate friend.

Test children of different ages and one adult with the following Binet tests: repeating sentences of varying lengths; repeating numerals; definitions; memory from reading; naming as many words as possible; use of code. Compare results.

CHAPTER XIX

ORGANIZED MENTAL LIFE

Mental Development. — In the last chapters (xi-xviii) we have examined the distinctive phenomena of central nervous activity, largely by the method of self-observation. The older investigators regarded these mental states and successions of states as the typical subject-matter of psychology. Under our definition the scope of the science is broader. The central phenomena form but one fragment of the chain of events which occur in the mutual interaction between the environment and the organism. The specific type of interaction which takes place by means of the nervous system and its adjuncts constitutes mental life, and the real subject-matter of psychology is the study of mental life as a whole.

Mental states, attitudes, and character are phenomena of the central adjustment process. They are by far the most significant phenomena of mental life in its higher stages of development. Yet they represent only a cross-section of the entire chain of activity denoted by the term *mental life.*

Viewed in its entirety, mental life includes all the activities which enter into behavior. But even this conception is incomplete. The behavior phenomena undergo constant change in the history of each individual. Mental life is an evolutionary process — a growth. We can scarcely reach a full understanding of its higher manifestations unless we take into account the paths along which this development proceeds. Broadly speaking, we find three lines of progress in mental life:

Differentiation of mental states
Mental organization
Systematic control

1. **Differentiation.** — The differentiation of mental states has been treated rather fully in preceding chapters.[1] In applying these results to organized mental life the point to emphasize is the great *qualitative variety* of mental states. The vast number of different perceptions, feelings, etc., which we experience serve as basis for an endless differentiation of behavior. Central complexity is the immediate source of the complexity observed in the behavior of higher organisms.

2. **Mental Organization.** — Every living being is an organized system of material particles. The type of organization found in living biological beings is called the *organic* type; an organic unit is called an *organism.*[2]

The biological or organic type of organization, as we have seen (ch. ii), is exceedingly complex. A living creature is able to maintain itself, repair structural damage within certain limits, increase its own size, and reproduce other beings like itself. All these functions are comprised in the notion of biological or organic life. An important feature of this type of organization is that the *process of organization is self-operating.* The activities of the cells and their components bring about structural differentiation and systematic organization of the entire organism. The evolution and development of an organism is not due to the working of some outside agency, in the sense that a locomotive is constructed by men and by means of machinery, neither of which is part of itself.

[1] See chs. ix–xviii.

[2] The similarity of the two terms *organism* (adj. organic) and *organization* (adj. organized) is confusing. *Organization* means an arrangement of constituent parts in a system such that they work together and bring about systematic results. The Red Cross society is just as much an 'organization' in this technical sense as a human being. A locomotive or a printing-press may be regarded also as organized matter — as an organization. An *organism* is one specific type of organization: that which has evolved among biological units. It simply increases the confusion if we extend the connotation of organism, as some sociologists do, to include social organization. Even more undesirable would be its extension to human-made machines.

This distinctive feature of biological organization should be borne in mind when we consider mental organization.

Mental organization rests upon a certain phase of the organic organization — the nervous system and the terminal organs which are connected with it. This system forms the 'structural basis' of mental life (ch. iii). It is the groundwork of mental organization. The general make-up of the nervous system and terminal organs is the result of organic operations. The formation of neurons and their topographical relations is an outcome of organic organization. To this extent mental organization is not a self-operating system.

But when we study the system in actual operation we find that the inherited and developed nervous structure is not the only factor in mental organization. The interaction between the living creature and his environment is more than a question of specific nerve mechanism. In the higher species, and particularly in man, it depends essentially upon the organized mass of central experiences which have developed during the individual's life-time. Each separate experience modifies the nerve structure to some extent, and subsequent experiences are affected by the totality of these past modifications.

When you manipulate your knife and fork at table, this response to the food stimuli is carried out in a certain specific way because of your many previous experiences of the same sort. You handle these implements differently than you would if your life had been spent in the backwoods, or in a savage community. You use them somewhat differently according as you have been brought up in America, France, Italy, or some other country. In this and other standardized forms of behavior, the mode of response to the specific stimulus has been molded through the operation of various stimuli — similar and dissimilar — in the past. These earlier stimuli have altered the nerve mechanism little by little so that it responds in certain particular ways.

In the two preceding chapters it has been shown that these

central modifications of the mechanism are not distinct and isolated. They affect one another and thereby develop *general tendencies* of behavior. The development of such tendencies is a process of organization. In this respect, mental organization constitutes a *self-acting system.* The system of interaction between the creature and his environment *organizes itself*, within the limits of capacity provided by the inherited structural basis.

Mental organization, then, depends upon both inherited *nerve structure* and the *modifications* which are wrought in that structure by use. The higher phases of mental life, such as language and rational activity, involve a long series of changes and integrations; these functions cannot be adequately described in terms of the original neural mechanism. The organization of experience is in large measure a functional process; it is perfected by its own operation.

Mental organization differs in this from human-made machines. A locomotive or a sewing-machine may 'wear down' somewhat through use, so that it works better after a time; but in the main the effects of use are destructive to human-made mechanisms. The mental mechanism on the other hand improves constantly through use, up to a certain final limit; its more complex achievements are attained only after a long process of functional development.

Factors which Determine Mental Organization. — In the preceding chapter the term *personality* was used to denote the total manifestation of an individual's organization at any given stage. According to the older, static view of mental life, man's personality was held to be wholly a product of heredity. The mind was considered an original endowment — something thrust full-fledged into the human body at the very beginning of the individual's separate existence. Growth and experience were supposed merely to remove the wrappings which concealed the true inner self and hampered its activity. The older psychology conceived of self or person-

ality as fully formed at the outset and not subject to development.

According to the evolutionary view, now generally accepted, man's personality, like the specific phases of his mental life, is a real growth. The self starts as a rudiment with the first experiences of the embryo, and gradually increases in complexity. The growth of personality and individuality continues throughout life, and ceases only when death disintegrates the nervous organization.[1] Personality is the result of progressive mental organization. Its specific manifestations serve as an index of the degree and variety which that organization has attained at any period of life.

Mental organization, as we have seen, is the joint product of two distinct factors: (1) the inherited neuro-terminal mechanism; (2) environmental forces which act upon this mechanism. The process of mental organization will be better understood, however, if we separate these into a number of more specific factors:

Inherited structure

Terminal organs and conducting neurons
Central system

Environmental and intra-organic forces

Disorganizing influences
Specific stimuli and general environmental conditions
Social environment
Educational influences

(*a.*) Terminal Organs and Conducting Neurons: The range of mental organization depends in large measure upon the variety and complexity of the receptors and effectors. A complex receptor organ, such as the eye, affords great possibilities in the way of manifold different experiences. The various senses supplement one another and in their totality give vastly more complete data of the external world than any one of them taken separately.

[1] See Appendix, "Personal Immortality," p. 442.

In the same way the multiplication of muscles affords opportunity for coördinated expression and for adapting our responses to the external situation. The conducting paths, both sensory and motor, form an integral part of the receiving and responding mechanism. Without these paths the terminal organs would be isolated and would bear no direct relation to the unified mental life.

(*b.*) Central System: The fundamental factor in determining mental organization is the central portion of the nervous system. An intricate system of neurons in the brain, and especially a highly developed cerebral cortex, gives opportunity for the growth of a high order of personality, while without this complex neural structure the range of a creature's mental development is extremely limited. The general type of nervous system which characterizes any species is primarily the product of heredity, though its development in typical form in the individual depends to some extent upon environmental conditions, since neural growth may be thwarted by malnutrition and other influences.

Man's superior mental organization is due chiefly to his inheritance of a highly complex cortical system, provided with a vast number of interconnecting neurons. Integration of stimuli, coördination of responses, and adjustment of response to stimulation all depend upon the central system and to a large extent upon the cortical tracts. These are all inherited structures.

(*c.*) Disorganizing Influences: The inherited mechanism of mental life is liable to be impaired in various ways by the action of outside forces. Our eyesight may be injured by overexposure to light or by some sharp body mutilating the eyeball. The loss of a foot or hand cripples our motor expression. Injury to the brain by a fall or other 'accident' often leads to serious disorganization of the adjustive functions.

Degeneration and impairment of mental organization occur even more frequently as a result of forces within the body it-

self. A tumor in the brain affects the structure or functioning of certain centers and this gives rise to pathological mental manifestations (aphasia, etc.). Malnutrition, disorders of digestion or other vital functions, use of narcotics, stimulants, and other poisons, alter the course of mental activity in various ways and affect character and personality correspondingly. Thomas Carlyle's pessimistic attitude is attributed to his dyspeptic condition. Diseases which destroy the tissues may affect the nerve substance or some of the receptors or effectors. This disorganization occurs in varying degrees, from deafness following measles to paresis due to venereal infection.

The most serious mental disorganization is due to conditions of permanent infection. Where parents are infected, this may modify, if not the germ cell itself, at least the embryonic development of the offspring. A large proportion of feeble-mindedness is attributable to this cause. Strictly speaking this is not inheritance, for the lack of mental development in such cases is not due to typical conditions in the germ cell. But it is an effect *transmitted* from parent to child, and on this account the retardation is often attributed to heredity.

Mental pathology covers a broad field and forms a distinct branch of psychology — two branches in fact, for there is a wide distinction between mental retardation and mental disorder (psychiatry). Each of these studies throws considerable light on normal psychology.

(*d.*) Specific Stimuli and General Environmental Conditions: The direct and indirect effects of specific stimuli have been examined at length in earlier chapters. The *systemic* stimuli, so far as they lead to responses which modify the organism, broaden the sphere of mental life somewhat. Our responsive activities to internal pain, for instance, constitute an interrelation between the organism and itself — not between creature and environment. Rubbing a bruised ankle,

taking medicine to cure a digestive trouble, are reactions which adjust the conditions within the organism itself, and bear no significant relation to the external environment.

General conditions of environment, such as climate and temperature, abundance or scarcity of food and material for protection and defense, play some part in determining mental organization; their influence is far less than that of specific situations.

(*e*.) SOCIAL ENVIRONMENT: The social environment or 'social atmosphere' is much more important in determining the higher stages of mental organization than stimuli from the ordinary physical environment. Language and the entire function of communication depend upon the presence of a social environment. It is reported that castaways show considerable retrogression in mental organization. Alexander Selkirk, whose solitary life for over four years on Juan Fernandez Island suggested the tale of *Robinson Crusoe,* lost much of his vocabulary and his facility to talk connectedly. Clear thinking is apt to be impaired by constant solitude, though alternation of solitary and social conditions often stimulates rational thought.

The extent to which the development of mental life depends upon social influences in childhood is shown by certain instances of children brought up in solitude or apart from human surroundings. In the case of Kaspar Hauser, who was apparently brought up almost without social intercourse, intellectual development was irremediably atrophied.[1] Helen Keller, cut off from social stimuli through blindness and deafness, made no progress in mental organization till taken in hand by an expert teacher.

Social influences act both focally and marginally. Much of our mental growth in childhood is due to 'unconscious absorption' of ideas and imitation of customs from those

[1] This may have been due to congenital factors, however. On the other hand the legendary tales of Romulus and Mowgli are quite untrue to life.

about us. Our mental organization is molded after the pattern of the community in which we live. An individual with a given heredity may become a notorious criminal or a power for good, according as he is placed in an unfavorable or favorable social environment.

(*f.*) Educational Influences: Education, in the sense of organized 'teaching,' constitutes a distinct factor in mental organization. It represents the *dynamic* influence of the social environment upon the individual. It is the systematic attempt of society to develop the mental organization of its members.

Teaching occurs in a rudimentary form in primitive races, but its main significance is seen in the higher stages of civilization. Here it exerts a preponderating influence in organizing mental life. Beginning with home and church training it extends through the schools to the university and to technical institutions of every sort. By these means mental growth is 'forced'—mental organization develops at a rate far exceeding that attained under passive social conditions.

Heredity and Environment. — Comparing mental with 'vital' life, we observe a great contrast in the relative importance of heredity and environment as factors in promoting organization. In both cases heredity furnishes the essential structural basis; but it determines the direction or trend of mental growth far less than that of general bodily growth.

Biological growth demands of the environment only a certain gross uniformity of physical conditions (temperature, atmospheric density, etc.) and adequate nutriment. Individual differences in environmental conditions produce modifications of bodily growth, but these variations are relatively slight compared with the uniformities common to the species.

In mental development, on the other hand, the individual variations due to environmental differences are enormous [1] —

[1] This would naturally be expected, since mental life depends upon interaction with environment.

particularly those due to the influence of social factors. Our mental heritage is chiefly an *equipment* which enables us to grow mentally. The direction actually taken by mental growth depends almost wholly upon social environment and education. The fullest organization of mental life is attained only when our inherited possibilities are utilized to the utmost through social imitation and training.

Types of Mental Organization. — If we compare individual human beings we observe many striking differences in degree and type of mental development. The study of variations in degree of organization (mental level) carries us into the field of genetic psychology, a territory too broad for examination here.[1]

The subject of qualitative differences in mental organization belongs to 'general psychology' to the extent that each type of personality represents the hypertrophy of some phase of mental life.

On the receptive side notable differences in *sensory* mental type appear, which have been the subject of some experimental investigation. One man is found to be distinctly 'visual' in type. In his case the visual data are habitually focalized and constitute the principal components in his mental states. He learns by reading better than by listening, his interest is in the microscope or in maps. If he is an author, his books abound in color terms and visual pictures.

Another person is found to be *auditory* in type. He understands oral instructions readily, learns more easily from lectures than from text-books; he is quick at 'mental' arithmetic. His auditory imagery and in most cases his appreciation of music are unusually developed.

A third belongs to the *kinesthetic* or motor type. With him language is primarily a motor phenomenon. His imagery is kinesthetic, he is apt at memorizing speeches, his interest is in

[1] One phase of the problem — intellectual growth — was touched upon in chapter xviii.

motor acts. The emphasis of his mental life is on the expressive side rather than the receptive.

It is a mistake to assume that each individual belongs distinctively to one of these types. In some cases the mental organization is rather evenly balanced. In many persons certain activities are preëminently of the visual type while others are based upon kinesthetic or auditory data. A man may be an 'auditory linguist' in one tongue and a 'visual linguist' in another. Apparently the only generalization justified so far by the study of sensory types is that most individuals belong to a specific type in some degree and in respect to certain mental operations.

A similar differentiation is observed in the organization of *character*. In certain individuals the intellectual side is overdeveloped, in others temperament, in others skill. How far these character types depend upon the prominence of elementary components of the corresponding sorts in daily experience is not yet known. The development of character types may be due primarily to inherited structural refinement of certain brain centers, or to unusually developed associative connections between certain centers. The results of experimental education demonstrate, however, that systematic training can at times direct the organization into definite types or smooth out certain prominences of type to a very considerable degree.

3. **Control.** — The third line of progress in mental life is *control*. We may distinguish between several phases of control:[1]

Control of responses
Control of environment
Self-control
Social control

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[1] The *types* of control treated in chapters xiv and xv depend upon differences in the mechanism by which adaptation is brought about. The *phases* discussed here differ in the sphere in which the adaptation occurs.

(*a.*) Control of Responses: The central adjustment of nerve impulses through experience tends to make the individual's motor activities continually more suited to the situation. The learning process (which is central adjustment) enables the creature to protect himself and gain food with less expenditure of energy and with fewer failures. There is a progressive improvement in his motor coördination. The individual gradually achieves *control of his own movements.* This is the fundamental aspect of control.

(*b.*) Control of Environment: A higher stage is reached when the environment itself is more or less permanently modified by our responsive activities in such a way as to assist our life processes. When primitive man prepared skins of animals and used them to clothe and protect himself, he advanced one step toward *control of his environment.* The making of forest trails, building of huts, sowing of fields, and domestication of animals are other early instances of man's active influences upon the physical world. In civilized man ships, railroads, harvesters, lighting plants, and all the products of industry may be regarded as instruments or means for the control of nature.

The key to this higher growth of control is found in the complex central process which one observes in himself as volition. We have noticed (ch. xiv) the tendency of voluntary expression to conform to the ideational factors in the experience. When the central mechanism is so developed that our images and thoughts lead to corresponding forms of activity, the way is open to control of the environment. The complex results attained in this direction by civilized man are due to a cumulative training of thought and volition. The highest attainments involve nothing psychologically new, except the social factor. Control of the external world is aided by social example and teaching, and more especially by the permanent graphic records which broaden the scope of man's social environment and preserve the acquisitions of each generation for use in future ages.

(*c.*) Self-control: Development of control along a distinctly different line occurs when man learns to inhibit or modify his own systemic and motor processes. This is illustrated in repression of the emotions and less obviously in a systematic regulation of one's daily work. Here the significant result is not so much the alteration of environment as systematic direction of phenomena within the body. The term *self-control* is commonly applied to the inhibitive side of this process, but it may well be broadened to include the guidance and active alteration of mental operations.

The attainments of civilized man in this field are as notable as his control over nature. He is not only ' master of his fate ' but ' captain of his soul.' The sphere of psychology is extended to include not merely the reaction of the creature upon the environment, but his reaction upon his own bodily and mental organization as well.

(*d.*) Social Control: Still another line of development is *social control.*[1] By means of language and other communicative expression human beings are able to guide the actions of their fellows and of lower animals. Here we have two standpoints to consider — that of the *controller* and the *controlled.* To the active agent in the social relation the results are not essentially unlike those attained in controlling his physical environment. But from the standpoint of the individual affected the phenomenon presents certain new features.

Mental organization may be either promoted or impeded to a large degree by social control. The process of teaching is one phase of the phenomenon, and a most useful one. Psychotherapy, the improvement of bodily and neural conditions by suggestion from others, is another phase, which covers a wide field. " Inspiration by example " is still another instance. On the other hand, one individual may come so

[1] The term is used by sociologists to include government and other organized social agencies. In general psychology it means control of one organism by another.

under the domination of another that his mental development is seriously thwarted. The slave and the professional hypnotic subject illustrate this deleterious working of social control. The result here is mental deterioration instead of evolution.

Personal Control and Personality. — The development of control depends upon the progressive organization of central adjustment. Every response, however complex, is determined by present stimuli and by the alterations which the resulting impulses undergo before they lead to motor expression. The significant alterations of nerve impulses are those which occur in the central region by way of summation, distribution, retention, and metabolic change, with resulting modification. These central alterations of impulses become systematized step by step with the organization of mental life. The systematic modification of central impulses gives rise to the various types of mental states and attitudes noticed in previous chapters. The final product of central organization is *personality*, which includes all these varieties of conscious experience.

If now we regard organized mental life as behavior, we can trace the results of its progressive organization in the various types of control just discussed. The final outcome from this standpoint is *personal control*, which represents the interworking of all the specific phases.

Speaking in terms of behavior, mental organization means the progressive coördination of responses, and their adjustment to the whole group of stimuli which affect the organism. In the earliest stage, behavior consists in isolated responses to isolated stimuli. Through evolution and individual development these separate activities gradually become unified. The final stage in the organization of behavior is *personal control of the total situation.*

General Summary of the Book

Psychology, as defined in the beginning of the book, is the scientific description and explanation of *mental life*, which denotes a type of process by which the environment affects the organic being and the organic being in turn affects the environment. The distinctive feature of this type of interaction is that it is mediated through the operation of a special mechanism known as the neuro-terminal system (ch. i). Accordingly as an essential basis for our study of mental life, we examined the general characteristics of organic beings or *organisms* (ch. ii) and the structure of the *neuro-terminal system* (ch. iii).

The elementary unit of the nervous system is the *neuron.* The activity of neurons is probably a chemical change which is propagated along the nerve fiber, accompanied by electrical disturbance. We noticed seven properties or distinguishable *operations* of neural activity: excitation, conduction, retention, metabolic variation, summation, distribution, and modification (ch. iv). As noted further on, these characters are observed in our own subjective experience as impression, suggestion, revival, vividness, combination, discrimination, and transformation (ch. viii).

The individual neurons are built up into a complex system of *arcs*, each arc consisting of three parts, the sensory, central, and motor segments, which are joined to form a circuit, the sensory end being connected with a special terminal organ called the receptor, and the motor end with another special organ called the effector. The operation of the nervous arc consists in the transmission of an impulse from end to end.

A nerve impulse starts with *stimulation* of some receptor by a force from outside the nervous system.[1] The effect is transmitted directly to a neighboring sensory neuron and arouses a nerve impulse, which is transmitted successively

[1] Not always from *outside the body.*

through the sensory, central, and motor segments of the arc. The motor impulse ultimately causes activity in some effector organ, which produces a ' motor effect ' upon the environment or upon the inner mechanism of the body. This final motor effect is called the *response.*

The significant part of the chain of neural activity is the operation of the central section of the arc, which *integrates* impulses from various sensory paths, and *coördinates* impulses passing into various motor paths. This central operation is called *adjustment;* it brings about responses which are more or less ' fit ' or ' adapted ' to the specific situation in which the organism is placed. The entire chain of processes in the circuit (stimulation — adjustment — response) taken together constitute *behavior* (ch. v.).

Mental life in the broadest sense is *behavior.* We examined the operation of behavior as a whole, taking up first the simpler types, *reflex* and *instinctive* behavior (ch. vi) and then the complex form called *intelligent* behavior (ch. vii).

In studying intelligence we found that the complex processes in the central section of the arc are the essential feature of the operation. These processes are not at present open to examination by objective methods; we examined them by the subjective method of *self-observation.*

The elementary data which make up our *conscious experiences* are of two sorts: *sensations* and *ideas.* Sensations are the original, primary components of experience. They arise directly from stimulation. Ideas are secondary or derivative data. They are not the direct result of stimulation, but arise in the brain and are due to the retention in some central neuron of the effects of past experiences. An idea may be regarded as the ' second edition ' of a sensation (ch. viii).

Sensations are classed according to the type of receptor which arouses them. Eleven different *senses* are distinguished. We examined each of these in turn (ch. ix, x).

The sensory data fall into three classes: *external, systemic,*

and *motor*, from which typically different sorts of experience arise. In all, four distinct kinds of components are distinguishable — the three varieties of sensory data and a single class of *ideational* data. The elementary components are not experienced separately in adult life; our experiences are combinations and transformations of these data (ch. xi).

A specific experience is called a *mental state.* Mental states may be classed as primary and secondary. Primary mental states are those in which some one variety of data predominates. They are classed as perceptions, imagery, feelings, and conations. A *perception* is a mental state in which external sensations predominate (ch. xii). In *imagery* the ideational data due to external sensations predominate. Imagery includes several distinct sorts: memory images, free images, anticipation images, imagination images, and general images. A *feeling* is a state in which systemic sensations are dominant. In *conations* the motor (especially kinesthetic) sensations predominate (ch. xiii).

Secondary mental states are those in which two or more different sorts of data are prominent. They are classed as emotions, sentiments, volitions, thought and language, and ideals and rational actions. In *emotions* both systemic and kinesthetic data are prominent; in *sentiments* ideational and systemic data; in *volition* ideational and kinesthetic data (ch. xiv).

In *thought* and *language* the original ideational and kinesthetic data are transformed into new and higher complex states through the social interrelations of individuals. A distinctive feature in thought and language is the verbal symbol. *Ideals* and *rational actions* are mental states in which all types of data except external sensations are prominent (ch. xv).

Mental life consists of a *succession* and transformation of mental states of these several sorts. The succession of *perceptions* depends largely upon environmental conditions; it is due to the serial order of the external stimuli affecting our

receptors. Successions of *imagery* and *thought*, on the other hand, depend primarily upon central conditions; one idea succeeds another as the impulse is modified in passing from one central neuron to another, each with its own characteristic retention set. The *general stream of experiences* which constitutes our conscious mental life includes both types of succession. Mental states of every sort combine and succeed one another as a result of changing external and internal conditions (ch. xvi).

When similar experiences occur repeatedly they tend to produce a general retention effect in the brain centers. A general set of this sort is called an *attitude*. There are several different kinds of attitudes; the most important are interest, desire, attention, dispositions, appreciation, and conscience. Each of these is based upon one of the fundamental types of mental states (ch. xvii).

Through repeated experiences, specific attitudes of each sort combine to form general attitudes, which constitute the *character* of the individual. The most prominent phases of character are temperament, intellectuality, skill, and morality.

The several phases of character, taken together, make up the general character of the individual, called his *personality* or *self*. Personality is the product of our heritage and of our entire past life (ch. xviii).

The mental life of each individual is constantly developing. Its growth is seen in the progressive *differentiation* of mental states and in the advance of *mental organization* and *control*.

Mental organization is the joint product of the inherited neuro-terminal mechanism and the environmental forces which act upon this mechanism. The cortical areas are the most important structural factors in determining its progress; social forces, especially the operation of systematic education, are the chief functional factors.

The growth of *control* follows several lines. It consists first of all in gaining control of our own bodily movements. In its

higher stages it results in control of the environment, self-control, and social control. The interworking of these phases results in *personal control.* This is the final outcome of organized behavior, just as personality is the final outcome of central organization or organized conscious experience. Personal control means that the individual himself is master of the situation in which he lives (ch. xix).

Special Conclusions. — We may emphasize in closing some of the more important facts regarding mental life which the book has aimed to bring out.

(1) The mental life of man and other creatures depends upon the presence of an *inherited neural mechanism.* Every conscious experience is accompanied by activity of the nervous system. Conscious experiences, or mental states, may be regarded as the subjective aspect of nerve activity. The complexity and effectiveness of these neural processes depend upon the degree of structural organization of the inherited neuro-terminal system. In man this system is highly organized; it is derived jointly from two parents and is due in part to each.

(2) Mental life depends also upon the presence of an *active environment* which operates upon the neuro-terminal system through the process called stimulation. The data which enter into experience are derived either directly or indirectly from stimuli outside the body, the internal stimuli being traceable ultimately to previous external stimulation. In man the social environment is an important factor in developing the higher phases of mental life.

(3) Mental life depends, accordingly, upon the *interaction of a creature and his environment by means of a neuro-terminal system.* Mental activity may be regarded as the stimulative effect of the environment upon the creature, with the resulting responsive effect of the creature upon the environment brought about by neural processes.

(4) Each specific manifestation of mental life may be stud-

ied as a sequence of stimulation, adjustment, and response; this chain of processes constitutes behavior. The most important factor in behavior is the *adjustment process;* this may be studied by the human individual through observation of his own experiences. Self-observation is examination of the central adjustment phenomena as mental states, or conscious experiences.

(5) The types of mental states found in man are a *gradual growth.* Even our attitudes, character, and personality undergo development during our life-time. They are not implanted at birth, but are formed by degrees. While the mental states which appear in the adult human individual may be investigated separately as static phenomena, the organization of mental life which produces them can only be adequately explained in genetic terms. Mental organization develops gradually in each individual; its structural basis has evolved step by step in race history.

(6) The evolution of every structure and of each type of process concerned in mental life depends upon its utility. In order to survive, an organism must be *adapted to its environment.* Like every other biological product the neural mechanism, by whose operation experiences are organized, is believed to have arisen originally through some chance variation — that is, through some new combination of factors in the germ cells. The persistence of the new structure is due to the fact that the individuals which possess it are more fitted to survive than those in which it is lacking. The same is true of the various forms of experience. The higher types of mental states (such as thought and language) which have grown up and established themselves in the human species, have arisen and persisted because they proved useful in mediating between man and his environment.

Collateral Reading:

Conklin, E. G., Heredity and Environment, ch. 6, and Introduction (Development of the Mind).
Hobhouse, L. T., Mind in Evolution (2d ed.), chs. 1, 18, 19.
Yerkes, R. M., Introduction to Psychology, chs. 30–32.
Ingenieros, J., Principios de psicologia biologica, chs. 6, 7.
Crampton, H. E., Doctrine of Evolution, ch. 6.
Thorndike, E. L., Educational Psychology (briefer course), ch. 27.
Angell, J. R., Chapters from Modern Psychology.

Practical Exercises:

Analyze how far your personality appears to be due to heredity and how far to your social environment.
What is your present idea of 'a mind'?
Describe observed instances of the growth of control in various phases of mental life — emotional display, sketching, systematic study, moral conduct; if possible take your own case in one of these instances.

APPENDIX

Some of the underlying principles assumed in psychology are still under debate. The results obtained up to the present are not thoroughly conclusive, and scientific investigators disagree in interpreting the facts. It is not possible within the limits of a text-book to discuss the merits of the conflicting interpretations. In this book the solution which appears most promising has been indicated in each case, with a footnote referring to the Appendix.

The debatable problems are discussed here for the benefit of advanced students. The aim is not so much to "settle the question," as to point out where the difficulty lies and why a certain answer has been adopted in the text. Arguments for opposing views will be found in the references.

PROBLEM I

THE MIND-BODY RELATION

Subjective and Objective Phenomena. — Since the time of Descartes considerable emphasis has been laid upon the distinction between *mind* and *matter*. Philosophers and scientists have been impressed with the "dual nature of being." As Descartes himself expressed it, *being* has two distinct modes: *thought* and *extension*. This notion has led to the belief, widely held, that there are two substances in the universe, a mental substance and a material substance. Even if this belief were universally accepted (which it is not), the problem of the ultimate nature of these substances need not trouble the scientist. For every science finds some elemental datum which it *assumes* without attempting to *explain*.

But the psychologist is confronted with another problem in

this connection, which cannot be so easily dismissed. All experience shows a certain relation between mental (subjective) phenomena and material (objective) phenomena. Apparently this is not a symmetrical relation. Many material or physical events occur which are not related to any discoverable events in conscious experience; but *our conscious experiences are all associated with certain physical events.* The physical events which accompany mental states are activities of the nerves and of the receptor and effector organs. Unless we decide at the outset to surround our science of psychology with an impenetrable Chinese Wall separating bodily activity from conscious experience, we find it expedient to adopt some *working hypothesis* which will account for their observed relation.

Recent psychology for the most part is divided between two conflicting interpretations of the relation between mental and physical phenomena. These hypotheses are called *Interactionism* and *Parallelism.* Both assume that subjective and objective phenomena are distinct classes of events.

According to the *Interaction* hypothesis physical events *cause* mental events, and conversely mental events cause physical changes. In other words, the two series are not simultaneous, but an event in one series produces the correlated event in the other. Brain activity causes thought; thought in turn produces activity in the brain. In support of this view are cited the effectiveness of conscious purpose and the selective character of the human will; also the persistence and evolution of consciousness in the animal series, which indicates that it plays an effective rôle in organic life.

The hypothesis of *Psychophysical Parallelism* differs from Interactionism in assuming that the correlated events in the two series occur simultaneously. According to this view the series of mental states runs parallel with the series of nerve impulses. Thought accompanies brain activity. The two series are in one-to-one relation, but they constitute distinct

phenomena. This interpretation is believed by its advocates to accord better with current theories of the persistence of force and conservation of energy than the Interaction hypothesis.

A third view, often confused with Parallelism, is the *Double-Aspect* hypothesis, which is adopted in the present book. This view has the support of several well-known psychologists (e.g., Fechner, Titchener) and is perhaps actually held by others who call themselves Parallelists. The Double-Aspect interpretation differs from both Interactionism and Parallelism in assuming that conscious and neural phenomena constitute *one single series* of events, and that their different appearance is merely due to different ways of observing them. When they " happen to me " they appear as conscious experiences; when I observe them indirectly, through perceiving the behavior of other beings by means of my senses, they appear in the form of motion, chemical change, and the like.

According to this hypothesis consciousness ' belongs to ' the activity of neurons as truly as the intensity or form of neural impulses belongs to this same activity. Just as in physics, when we discuss the properties of *masses* we find correlated phenomena, such as *surface* relations, which may or may not be studied but belong to the same group of phenomena, so in biology when we examine the *properties of nerve substance* we observe certain correlated phenomena called *conscious experiences*. They form part of the ' total description' of nerve activity. In physics the same event or group of events may be studied through several different manifestations: we observe increase in heat through rise of mercury in a bulb or through the fusing of some metal. Neural events, according to the Double-Aspect hypothesis, are likewise observable either as behavior or as ' our own ' experiences.

The Double-Aspect hypothesis is adopted here because it does not clash with observed facts and because it seems to

provide the best working tool for psychological investigation, It enables us to bring the results of objective and subjective observation into coöperation — using our physiological and behavior material to bridge the gaps in conscious experience, and using the results of self-observation to supply the missing data of brain activity.

Parallelism divides the organic world into two independent sets of events, which go on simultaneously and correspondingly but are entirely distinct from each other. There is a suggestion of 'preëstablished harmony' between the two sets which seems to require explanation. The Interaction theory would fill this demand effectually if it really 'worked.' But so far no satisfactory statement has been formulated to describe *how* neural events act upon consciousness, nor *how* conscious states work upon the nervous system. The argument for Interactionism, so far as it is based upon the phenomena of Volition and Purpose, seems to rest upon incomplete or faulty observation and analysis of these phenomena.

It should be remembered that the whole problem is still under discussion. Each of the three theories mentioned has a respectable following; the student must choose for himself among them. Whichever interpretation he adopts should be treated merely as a working hypothesis, subject to revision if a better explanation can be found.

Perception of the External World. — The term *introspection* is commonly used to denote observation of our own conscious experiences. The word is confusing, for it seems to imply turning our inspection 'inward,' either to the organic feelings which originate within our body or to the images which are localized in the brain centers. Even the term *self-observation* is open to this misconstruction if we emphasize the word 'self.' Self-observation means observing the effects of external stimuli quite as much as observing the internal components of our experiences. As a matter of fact everything that "happens to me" is material for my self-observation.

There is a real problem connected with *external* self-observation which perplexes the student of psychology. How is it that the same events are at once *experiences* and *objective phenomena?* How can the same thing be a book outside my body and something which I experience as blue, oblong, thick, heavy? A consistent interpretation of the facts is by no means easy. Various hypotheses have been proposed to explain the relation of the perceiving individual to the perceived object.[1]

A solution of the difficulty is suggested by the double-aspect hypothesis, though many psychologists do not regard it as a satisfactory interpretation of the facts. The world about us consists of electrons, grouped into atoms, molecules, cells, and organisms. These objects stimulate our receptors either by direct contact or by means of waves and emanations. The effect of stimulation is carried by our sensory nerves to the brain. When the effect occurs in your own brain it is your experience. What we experience immediately, then, is not the trees, houses, books, men, etc., situated in the outer world beyond the body, but the *cerebral effects* of stimulation by these objects. The outer world is brought in to us — we do not go forth and explore it.[2]

The point to emphasize is the *cerebral location of perceptual experience.* Whatever illusions and distortions occur in perception are due to defects in the transmission process, anomalies in grouping the material, or other central factors.

But how comes it that the things which we perceive appear to us to lie *outside* of our body and often at a distance? The answer seems to hinge upon the ' projection ' operation, which is one of the varieties of transformation that the sensory data undergo. The experience of ' extended space ' is just as

[1] In philosophy this is called the *problem of knowledge,* or *epistemology.*

[2] When we hear a friend's voice over the telephone the vocal characteristics are conveyed through a long circuit in form of electric waves, finally reaching our ear. Yet we are undoubtedly "hearing his voice." The case of neural transmission is analogous.

much experience as the quality 'red' or the quality 'sweet'; in each case the character of the experience corresponds to a character of the stimulus. The two are *congruent* though they may not *resemble* each other.

After all, perception of objects as situated at a distance from us simply means that the data stand in certain space relations to the visual, tactile, and kinesthetic perceptions of our *body;* the sensory data from our body and other objects pass through the same neural paths and are combined in perceptual experiences. An argument for this interpretation is found in stereoscopic perception. Here the data are two flat photographic pictures, slightly different from each other. When we observe them under proper conditions they are perceived as a single 'solid' object, projected considerably beyond the actual plane of the photographs.

Thought-Transference; Psychical Research. — A question of considerable importance for psychology is whether organism and environment can interact in a mental way without the medium of the sensory and motor conducting systems. This problem is not necessarily bound up with that of the relation between consciousness and the nervous system (interactionism). Even under the parallelistic and double-aspect interpretations it is legitimate to inquire whether the *central* nervous mechanism and the environment do not at times interact by other means than through the sensory and motor nerves.

In this as in all scientific problems what we have to do is to collect data and weigh the evidence. Two questions of fact are involved in the problem of *thought-transference:*

(1) Does the brain (or consciousness) receive impressions from the outer world directly? This issue is called *Telepathy.*

(2) Is the brain capable of producing changes in the outer world directly? This is the issue of *Telekinesis.*

Telepathy has been far more carefully studied than Telekinesis. The investigations deal chiefly with social data —

the supposed transfer of thoughts from one person to another through non-nervous channels.

The Societies for Psychical Research have examined and reported a host of instances in which individuals have apparently received information from a distance by means which preclude the hypothesis of ordinary sensory communication. A man reports that he dreamed of his mother's death at the precise instant when the event occurred; or he claims to have had a haunting thought of the event in waking life. Clairvoyants demonstrate their apparent ability to read messages blindfold, to describe an object lying in a distant room, to tell what one is thinking about, etc. Such reports, collected by sincere and unimpeachable scientists, fill volumes of the *Proceedings* of these societies. Psychologists are not agreed as to whether these occurrences are actually telepathic. William James was a staunch supporter of psychical research investigations; but so far as known he never definitely expressed either belief or disbelief in the telepathic character of the phenomena. Contemporary American psychologists for the most part reject the telepathic interpretation.

In this book the phenomena are not treated, because the collected evidence does not appear to substantiate the claim that they are due to direct thought-transference. Many of the phenomena reported may be explained according to well-known mental and physical processes; the residue may probably be attributed to these also. The arguments against the acceptance of the telepathic hypothesis are as follows:

(1) Faulty Memory: In many cases the temporal coincidence has proved on investigation to be faulty. The thought of a friend's death may have occurred some time before or after the event. In course of time we forget the discrepancy and come to believe that the two events coincided.

(2) Chance Coincidence: The statistics are weighted in one direction. If a premonition of death coincides closely with the event, it is remembered and reported; if not, it is

forgotten. The strongest premonition the present writer ever had was in 1900, when he felt sure a cable would announce the death of a near relative. The person in question is still alive and hearty. If all such *negative* cases were reported the ratio of fulfillments to total cases might not exceed the theory of chances. The element of 'reasonable expectation' also impairs the evidential value of certain coincidences; if a friend is seriously ill we are not unlikely to have thoughts of his death.

(3) COLLUSION AND FRAUD: The experimental investigations of clairvoyance are not open to either of the above objections. But in many cases it has been shown, either that information is given to the 'percipient' by some accomplice through ordinary sense channels, or that the percipient himself used sensory means, such as seeing under the blindfold, exchanging one envelope for another, etc.

Even among naturally honest folk there is a strong temptation to secure striking results. One important set of tests reported in good faith by the Psychical Research Society were afterwards shown to involve collusion between the percipient and her sister. The writer confesses to having been a confederate during his college days in some parlor 'experiments' which for a time convinced a large group of classmates who were not in the conspiracy. How far this explanation may be applied to serious investigations is a delicate question. The sincerity of the Psychical Research scientists is above suspicion; but the good faith of their human material is not always to be relied upon — neither is it by any means certain that the investigators are acquainted with *all* possible varieties of deception. Every new fraud and every new means of deception discovered casts additional doubt on the validity of the phenomena.

(4) UNOBSERVED SENSORY IMPULSES: Thought is ordinarily due to sensory impulses; but these impulses are transformed into new modes. When we are reading, the separate printed

characters are rarely observed. At times whole sentences are not observed as printed words: the stimuli are transformed at once into images and thoughts.

There are many ways in which our thoughts may be shaped and molded by sensory indications so faint that another person fails to observe them, even though he tries his level best to pick up every clue. In certain states of hyperesthesia the patient is able to distinguish one blank page from another through microscopic differences in texture. Slight 'imperceptible' adjustments of the vocal organs which accompany thought may be correctly interpreted by the percipient. Alterations in breathing, minute 'attitude' expressions may be read by a trained observer. In every-day life we often 'feel the tenseness' of the social environment or 'open up' in a more congenial atmosphere, though the distinguishing marks of the situation are too indefinable to be described in language. The operation of such subliminal factors in directing our thoughts is far more common than is ordinarily realized. In many cases it seems quite possible to explain the phenomena in question by these unobserved sensory data without assuming telepathic communication.

(5) The Trend of Evolution: The world of organisms has built up a tremendously complex mechanism consisting of receptors, sensory nerve-paths, and centers, whose function is to convey and integrate impressions from the outer world. This mechanism has evolved slowly in race history, presumably by chance variation and natural selection. If some simpler means of conveyance is available, as claimed, it seems highly probable that at some point in the course of history a systematic mechanism for this would have been perfected and become a dominant factor in mental life. In other words, the fact that a complex nerve mechanism has evolved *everywhere* among the higher species is presumption against the existence of the simpler receptive mechanism involved in telepathy.

Telekinesis, the supposed production of motion in objects

outside the body by mere volition, has not been so extensively investigated as the opposite phase of thought-transference. If by telekinesis is meant causing motion in masses of *inorganic* matter, the phenomenon is open to more rigid experimental tests today than telepathy. A few instances have been reported by scientific observers in which a physical object (such as a balance) has moved up or down apparently at the will or thought of the observer without muscular action on his part.

These results have not been accepted by physicists generally. It has been suggested that they involve faulty observation. It is important that the tests be repeated under rigid experimental conditions by many independent investigators. Only in this way will the validity of the telekinetic hypothesis be definitely proved or disproved.[1]

Personal Immortality. — The question whether human personality survives death and organic dissolution has engaged the attention of thinkers since the dawn of science. It is in fact a problem of more than theoretical interest. The persistence of our personal identity beyond the span of our life-time is a factor of some practical importance in formulating our career and determining our program of conduct.

The problem is germane to psychology, yet it is avoided in most recent text-books. The reason for this attitude is easily stated. Psychology in its present stage of development affords no real indication of the answer to be given. There is no direct evidence of personal survival in the phenomena of mental life. Certain analogies indeed may be cited for an affirmative view. It is possible, also, that the finer traces of mental organization persist after the gross organization of the body has become disintegrated. On the other hand hu-

[1] Recently some experiments upon telepathy by the use of laboratory apparatus have been undertaken at Harvard and elsewhere. The results of such experiments, carried out under carefully controlled conditions, should be far more evidential of the truth (or falsity) of the hypothesis than volumes of mediumistic phenomena.

man personality now appears to be closely bound up with an organization consisting of many neurons, and the interrelation of the separate neurons is lost at death.

Numerous instances of supposed communication with the dead have been collected by the Societies for Psychical Research; but for the most part their validity is open to doubt. The messages reported do not indicate a high level of mental organization, such as in many cases their reputed authors possessed in life.

Possibly future investigations either in psychology proper or in the field of psychical research will furnish conclusive, or at least satisfactory evidence. At present, scientific psychology neither affirms nor denies personal immortality.

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PROBLEM II

MECHANISM AND PURPOSE

Purpose in Organic Growth. — The phenomena of growth and regeneration in organisms are strikingly unique. A creature of any given species develops from a fairly simple cell to a complex, differentiated organism which resembles the other organisms of that species both as a whole and part by part. In the lower species and in the earlier stages of embryonic growth, if a portion of the body be cut away (by accident or experimentally) the missing part is restored and the new growth is similar to the original. Both " growth to type " and " restoration to type " are processes quite different from anything observed in the inorganic realm. They are activities apparently *guided* toward bringing about certain future results.

The question therefore arises: Is the apparent guidance of organic growth due to a specific kind of force, different in sort from physical and chemical forces — a force or agent which operates only within living organisms? Certain biologists believe this to be the case. They point to the fact that the vital processes ' look ahead ' — that the successive stages in growth are means to an end, — whereas inorganic processes are merely transformations of prior conditions. This hypothesis is called *Vitalism.* The great majority of contemporary biologists, on the other hand, believe that the forces which operate in organic growth are merely complex manifestations of the same physical and chemical processes which operate throughout the inorganic world. This hypothesis is known as *Mechanism.*

The processes which occur in growth are still in course of investigation. The direct evidence at present favors the

mechanistic contention: all the physiological processes so far observed are chemical and physical in character. But the results are as yet very incomplete and do not justify a final conclusion.

The difficulty is two-fold: (1) The growth processes are so complicated that we can only observe them piecemeal. We cannot marshal the entire array of coöperating factors which produce mitosis and enlargement in individual cells and interaction between cells. (2) The investigations have been conducted wholly along physical and chemical lines, so that it is to be expected that they would bring to light only physical and chemical factors. Hence, unless we chance to stumble upon some inexplicable result, they would afford us no evidence of the presence of a vital force.

On the other hand it should be remembered that the Vitalists have not succeeded in formulating any definite description of the character or workings of the supposed 'vital force.' It is a general maxim of science to explain the unknown in terms of the known, and so far this principle has always proved correct. We do not assume a special type of force in the motions of the planets; they are explained in terms of gravity, like the fall of bodies toward the earth. In the present instance both this general maxim and the weight of empirical evidence point to the mechanistic interpretation of growth and the other vital processes. The demonstration is not conclusive, since a *crucial test* is still lacking. But the burden of proof seems to rest with the Vitalists to demonstrate the actual existence of a specific type of force in vital phenomena.

The apparently 'purposive' character of growth may be explained without assuming the agency of a guiding force if we interpret the individual life of organisms in terms of their race history.

The chain of reasoning on which this interpretation rests is as follows: In the evolution of species each new organ or modification of an organ is assumed to have appeared originally as

a chance variation. Many such variations have occurred in successive generations — some beneficial, some detrimental, some neutral. Detrimental and beneficial variations are equally probable. ' But detrimental variations hamper their possessors in their competition with others of the species to secure food or protection from enemies, while beneficial variations render their possessors better able to secure food or escape danger. Thus the possessors of new *favorable* variations are more likely to attain maturity and produce many descendants. The beneficial form of organ accordingly tends to spread more and more among the species, while the less favorable types tend to disappear.

The variations which count in evolution are those based upon alterations in the germ cell. No modification of other cells affects the offspring; characters acquired after birth may help or hinder the individual himself, but they are not transmitted to succeeding generations.

Now to apply this to individual history. The whole course of a creature's growth is mapped out by the constitution of the germ cell from which he originates. The constitution of any individual germ cell is the result of variations which have occurred one after another in past generations. The variations which have persisted and are *now found in this particular germ cell* are consequently not of the average hit-or-miss sort — they are such as have *proved their utility* by surviving. In a word, individual growth is purposive (in the sense of meeting the future circumstances of the creature), not because it is controlled by a guiding force, but because the constitution of the germ cell which determines growth has been subjected to a selective process.

Conscious Purpose. — The behavior of organisms exhibits ' future reference ' to a more marked degree than their vital processes. This characteristic is manifested in both instinctive and intelligent responses, but is most clearly observed in the conscious experiences of human beings. We ' look

ahead' and plan our actions with a view to bringing about some definite result. The future outcome is already foreseen in thought. Such experience is called *conscious purpose.* The pictured result is called an *end,* the intermediate actions are termed *means,* and the initial mental state is a *forethought* or purposive thought.

The fact that we are able to picture future situations is deemed by some psychologists to constitute a distinguishing mark of conscious behavior. This conscious component is supposed to differentiate intelligent from non-intelligent acts. Purposive thought, like other types of thought, leads to motor activity; and if the ability to picture the future is solely a character of consciousness, it follows that consciousness is itself a factor in determining the course of activity. In other words, according to this view consciousness is not merely a *characteristic* of neural activity; but it is a *force* or guiding activity in itself. This interpretation of purposive activity is called *Voluntarism,* since it emphasizes in peculiar fashion the volitional type of experience.[1]

Voluntarism is generally associated with the Interaction interpretation of the mind-body relation. It assumes that mental activity is something distinct from neural activity. The mind attains its forethoughts, and indeed its whole grasp of the 'situation,' by certain specific processes of its own, utilizing the data furnished by the senses merely as a basis. It then initiates a course of action — conscious purposive action — which produces material results radically different from any which could otherwise be attained.

Opposed to this interpretation is the view that purposive behavior proceeds along substantially the same lines as other types of behavior — that it is fully determined by neural activity, and that all the transformations involved in the chain of events may be expressed in terms of physical and chemical

[1] There are several variations of the hypothesis which emphasize other types of experience.

processes. This interpretation, which may be called *Psychological Mechanism*, has been adopted in the present book. The following arguments may be mentioned in its favor:

A large part of the difficulty in explaining purposive activity is due to the extreme complexity of the phenomena involved. The Voluntarists assume that this complexity implies a radically new type of behavior. But complexity only means that the phenomena in question are difficult to analyze. It affords no real ground for assuming novelty of constitution. In spite of this complexity it is possible to analyze purposive behavior into simpler and more familiar phenomena. We can trace its sources to two well-known features of the nervous mechanism: *distant sensation* and *retention.*

Perception combines data from the distant senses with those from the contiguous senses. We see a ball coming toward us before it strikes our body. The response may be to the distant stimulus alone, or to the contiguous stimulus alone, or to their combination. If the ball strikes us heavily and gives rise to pain, we react to the pain stimulus. But the whole series of stimuli leave retention traces in the cortical centers. The next time a ball comes toward us the visual stimulus may arouse memory images of the entire succession of events; the memory of the former blow may arise before the ball reaches us, and we then react to the enlarged situation, which comprises the distant ball and the previous pain. Owing to the uniformity of nature, our responses to such situations tend to become *suitable* to the course of events. We dodge the ball, or we catch it in our hands. *The purpose image, then, is based upon a memory image aroused by distant-sense data;* the fitness of the ensuing course of action is due to the uniformity of nature.

Simple types of purposive behavior are observed among animals. When a dog chases a rabbit the locomotor activity is part of the feeding response, though it precedes the dog's contact with his prey. More than this, as Perry points out,

the salivary and gastric processes in the dog begin while he is still chasing the rabbit. All these activities are purposive; *the response begins before the total situation is presented* through the receptors; — it is *anticipatory.*

In all such cases there is central integration and adjustment. The anticipatory image is a mental state as well as a complex motor impulse. The Psychological Mechanist differs from the Voluntarist chiefly in his interpretation of the causal relation between the central and motor phenomena. The Voluntarist regards the animal's consciousness as a separate factor in the determination of action; the Mechanist believes that the whole sequence of physiological changes may be expressed in terms of physical and chemical processes — that in all purposive behavior the entire series of physical events follows the " line of least physical resistance."

Space will not allow us to follow out here the development of purposive activity into its higher complexities. It is a far cry from catching a ball to planning one's whole life career. The Psychological Mechanist is hampered by the intricacy of the factors; but he believes that by patient research they will eventually be isolated and shown to be merely complications of the same physical and chemical processes which make up simple purposive action.

In accounting for behavior, as in solving the problem of growth, the burden of proof seems to rest upon those who would introduce a novel process. Voluntarism is called upon to give an understandable account of the new force which it assumes. This it has not succeeded in doing up to the present.

Psychological Mechanism does not minimize the importance of consciousness in life nor its value in scientific research. According to the mechanistic interpretation, however, consciousness is not an active *force,* capable of producing changes. It is rather a *characteristic* of certain natural events; — a datum to be taken into account in scientific investigation and

apparently capable of furnishing valuable indications regarding cerebral processes and mental life generally.[1]

Free-Will, Determinism, and Responsibility. — The Voluntaristic hypothesis usually carries with it the view that voluntary acts are not fully determined by stimuli, nerve structure, and past experience. Given the situation as presented to the conscious individual by these three factors, a man is nevertheless 'free' to decide upon his course of action and to direct his movements accordingly. This interpretation of conscious behavior is called Free-Will or *Indeterminism*. According to the Indeterminist, at certain points in the sequence of events the course of physical motion or chemical changes in the brain is not an exact resultant of the material forces which are operating; certain physiological processes are checked (inhibited) or their direction is altered by 'conscious determination.' If the Interaction view be adopted there is nothing self-contradictory or absurd in this conclusion. Conscious processes, if independent of physiological processes, may certainly follow different 'laws' from the latter. The balance of probabilities, however, seems to favor the opposite interpretation — *Determinism.*

(1) There are countless demonstrations of the conservation of energy. The physical law that motion follows the line of least resistance has been verified so far as careful research has been able to test it.

(2) The actual workings of volition are capable of being explained according to physical and chemical principles so far as their intricacy permits the analysis.

(3) Even though at times we are conscious that we determine our acts independently of the situation, social statistics

[1] A third alternative interpretation of the facts is *Behaviorism,* which swings to the other extreme. The Behaviorist contends that the data of consciousness should be ruled out of science altogether because they are not causal factors. This narrowing of the scope of science has not justified itself up to the present. Self-observation has proved more useful than the study of behavior in investigating the phenomena of human mental life.

indicate that in the aggregate such acts really follow the lines marked out by conditions of heredity and environment. Crime and benevolence, taken in the aggregate, vary as functions of the social *milieu* and biological inheritance of the group. Even suicide fluctuates with community conditions.

One reason given by many for adopting the Indeterministic view is that ' free-will ' affords the most satisfactory basis for moral responsibility. For if a man's actions are completely determined by his heredity and his environment, how can he be ' held responsible ' for what he does?

Stated in this form the problem lies beyond the sphere of psychological investigation. But the psychologist may properly ask: What does ethics mean by ' moral responsibility ' and ' holding a man responsible '? [1] If a man's heritage and training do not measure his degree of responsibility, what does? Are his responsible acts determined by pure chance?

A favorite interpretation of modern Indeterminists is that the determining factor (outside of heredity and environment) is not chance, but ' personality.' Here we return to psychological territory again. Psychology traces the growing complexity of life from elementary sensations to complex mental states and attitudes; a man's character and personality appear as the outcome, the culmination, of his past mental life. Personality is the result of environing forces working constantly upon an inherited mechanism. Thus we are brought to the Deterministic interpretation unless we identify responsibility with random decision — unless responsible acts are haphazard events.

The science of ethics appears to require some reinterpretation to adjust it to the results of modern psychological research. The older conception of moral responsibility in particular seems to need revision. Responsibility, after all, may

[1] Legally, an imbecile or an insane man is not held responsible for his acts. An animal is not morally responsible. A human child is held only partly responsible. On the other hand no amount of adverse *environmental* influences absolve a man from responsibility in the eyes of the law.

be not so much a basis for unfriendly recrimination and judicial retribution. It may be rather the measure of a man's mental level, of the degree of organization which his adjustive mechanism has attained.

Personification of Natural Phenomena. — In the course of this discussion we have noticed several hypotheses which at one stage or another run counter to a thoroughgoing mechanistic interpretation of nature. They assume that at some point or points in history new data appear or a new kind of force manifests itself.

Some of the supposed new forces or data concern psychologists only indirectly. But the theories may be classed together because they typify a general tendency of scientific thought — a tendency which manifests itself most noticeably in the earlier stages of every science. Primitive science *personifies* complex phenomena; it treats certain of them as *directing agents* in the course of events.

In physics and chemistry these personal agencies have been gradually discarded. In biology the complex phenomenon of *life* is still hypostasized by the Vitalists. Similarly in the domain of mental phenomena *will*, *thought*, and *personality* are hypostasized by certain psychologists as determiners of activity. There is also a type of psychology which considers *consciousness* and *intelligence* as generators of movements, rather than as characters of phenomena, like beauty or transparency.

The Mechanist finds such explanations unsatisfactory because they do not attempt to show *how* these personal agencies operate. To say that vital force causes growth, that intelligence or will causes muscular movement, does not indicate the manner in which the physical changes involved in growth or muscular movement are affected. It merely gives a convenient name to the process.

In the old magic, pronouncing some word, such as "Abracadabra," was supposed to bring about tremendous results.

It was never explained how the sound vibrations operated. In fact, the mystery of the process was especially emphasized. The Mechanist sees a similar mystical tendency in modern personificatory interpretations of nature.

The underlying assumption of a 'personal agency' may prove correct in one form or another. But the trend of scientific progress is all in the other direction. As our knowledge of natural phenomena advances these personal agencies are one by one resolved into physical and chemical operations of the phenomena themselves. The evidence today seems clearly to favor the Mechanistic interpretation as a working hypothesis in psychology as in other fields of science.

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PROBLEM III

NEURAL ACTIVITY

Nature and Modal Variation of the Nerve Impulse. — It has long been known that some sort of electric phenomenon accompanies the transmission of the nerve impulse. This is clearly indicated by fluctuations which are observed in the galvanometer needle during the process. It has naturally led to the assumption that neural conduction is primarily an electric phenomenon. Recently it has been found that a chemical change also takes place in the nerve fiber during the activity caused by stimulation. The amount of carbon dioxide is increased in the active nerve to about double that of the resting nerve. When the activity ceases the over-supply of CO_2 is eliminated.

On these grounds Herrick thinks it probable that "the transmission of a nervous impulse involves a wave of chemical change throughout the length of the nerve fiber, though a change of a quite different character from that occurring in the cell body during its functional activity" of nutrition and growth (*Introd. to Neurol.* p. 97).[1] At present, then, we may regard the nerve impulse as a 'chemo-electric' phenomenon, with greater stress laid, perhaps, on the chemical side.

It may strike the student as extraordinary that the nature of so patent a phenomenon as the nerve impulse should still be in doubt. One reason is that the neurons are surrounded by other tissue, and that it is difficult to separate them from the surrounding mass without functional disturbance. The ex-

[1] The slow rate of nerve conduction has also been urged as an argument against regarding the phenomenon as a simple electric discharge. But the varying rate of electric transmission in core conductors renders this argument questionable.

periments in nerve conduction have generally been performed upon excised nerve and we cannot judge whether the artificial stimulation used in this work produces a genuine nerve impulse. In these experiments electrical stimulation is employed and the observed effects are electrical. No means have been found to determine what *other* processes are going on in the fiber except the very slight chemical changes recently discovered. The interpretation of neural activity has for these reasons been based largely upon the analogy of electrical phenomena.

Many physiologists assume that the sensory nerve impulse varies in one 'dimension' only; they recognize variations in *intensity*, but not variations in kind or *mode*. They attribute the variety in the effects to combinations of impulses in different paths which meet at common synapses and spread along divergent paths again.

In opposition to this view the *modal differentiation* of the nerve impulse is adopted in the present book, for the following reasons:

(1) Many transmission phenomena which occur in nature vary in two independent ways. This is noticed especially in undulatory motion. Sound waves vary in rate as well as amplitude; the same is true of light waves. The nerve impulse may well be analogous to these types of transmission.

(2) The central effects of nerve impulses, observed as sensations, differ in quality as well as intensity. These cortical phenomena are the direct result of stimulation. Thus at one end of the series there are differences in *rate* (e.g., among visual stimuli), at the other end differences in *quality* (among visual sensations). It seems highly probable, then, that the intermediate processes (impulses in the optic nerve) vary in a corresponding way. This species of variation, which is independent of intensity (amplitude), is what we mean by *mode*.

How far this interpretation is correct can only be determined by more thorough research into nerve physiology.

Assuming its truth, it affords a simple and intelligible explanation of our conscious experiences.

Retention, Metabolism, and Modification. — The phenomena of retention and recall have been noted since the beginning of psychological observation. Aristotle, in his scientific treatises, discussed recollection and formulated some of its principles. In modern times, since the fundamental importance of the nervous system in mental life came to be recognized, the problem has been to discover the nature of the effect which remains over in the nervous system, and how this after-effect operates to bring about the phenomenon of revival.

We are still at sea as to the nature of neural retention. If little is known as to the character of the nerve impulse, still less has been discovered about the effect remaining after its passage. Direct investigation has revealed nothing so far; we know beyond peradventure that *some* effect is retained, and that is about all. The retention effect is probably not in the cell body, whose function is apparently concerned with growth and nutrition of the neuron; it is therefore some change either in the cell fiber, or at the synapse, or both.

Contemporary investigators tend to place the 'seat' of retention at the synapse. What is retained, according to this view, is the *permeability* of a given synapse due to the passage of an impulse, and an *increase of permeability* after repeated passages across the same synapse. Recall is explained as the subsequent passage of impulses over the same group of synapses. The course of the totality of impulses through the cortical paths at a given instant is interpreted as involving adjustment and balance of many synaptic resistances in all paths of the central field.

According to the hypothesis adopted in this book, the synaptic resistance and permeability is only part of the story. Another and more important factor in retention is some sort of *trace* or *set* left in the fiber itself, due to the *mode* of the

impulse which has affected it. Since our hypothesis calls for two factors (set of the nerve fiber and synaptic resistance), it is less simple than the other view, which explains the phenomenon in terms of a single factor — synaptic resistance. It therefore requires justification; the burden of proof rests upon its advocates, according to the canons of science.

The reason for preferring the less simple interpretation in this particular case is that retention is subject to *two* influences, fatigue and habit, which work in opposite ways.

(1) Certain metabolic changes in the body outside of the nervous system affect neural activity. They are largely katabolic, and impair the function of neural activity. In this case *impairment*, or 'fatigue,' is the positive phenomenon; 'restoration' is merely recovery from the effects of fatigue.

(2) Retention of the effects of previous excitation is a phenomenon of the opposite sort. Repetition strengthens the retention. Here *improvement* of connection is the positive phenomenon; lapse of time and intervention of other neural happenings merely lessen the retention effect.

Inasmuch then as we have two counterworking types of effect to deal with, we are justified in assuming two distinct types of operation to produce these effects. The *fatigue* process probably occurs at the synapses, since elsewhere the neurons are protected (insulated) from external influence. The *retention* process, on the other hand, is closely bound up with neural activity and may be effective either at the synapses or in the nerve fibers.

Now if we adopt the modal hypothesis (for reasons given above), it seems likely that various modes of impulse produce different effects in their passage through neurons, and these effects not improbably leave a trace or set of some sort in the neural substance. In physics we observe a set in certain bodies remaining as an after-effect of forces acting upon them. A violin sounding-board becomes attuned to certain vibrations if played constantly by a master in the same standard

of pitch. The receding tide leaves ridges in the sand which vary according to the size of the waves. Many analogies of various sorts indicate the likelihood of some lasting impression in the nerve substance as a result of conduction — impressions which assume a *specific form* if the same mode of impulse passes through the nerve repeatedly.

This interpretation of retention would explain why the optic region always affords visual sensations, even when stimulated electrically or by other non-visual activities. It explains the resemblance of the memory image to the original sensation. It enables us to understand also the occurrence of ideation in general. A 'deep' trace in a central neuron would tend to alter the mode of any impulse entering it, so that the mode of an impulse is in many cases modified into the mode of the retention trace.

The laws of association may be readily interpreted under this hypothesis in neural terms. An impulse passes more easily into a neuron which is partly 'attuned' to its mode — that is, into one whose retention set is similar to the mode of the present impulse. It is a question not merely of the relative permeability of the several discharging synapses from a given neuron, but also of similarity between (*a*) the set in the neurons *beyond* the branch-points and (*b*) the mode of present impulse.

The complexity of our perceptions and thoughts, and the new qualities which characterize many such complex experiences, find an explanation in the modal hypothesis. In many physical processes the combination of two or more different factors produces a complex effect. Two simple sound waves or light waves unite to form a complex vibration. We may assume, similarly, that when many nerve impulses of various modes gather together in a single central neuron, the resulting impulse (and trace) in that neuron will be correspondingly complex.

It is observed also in certain physical phenomena that the

rhythm, rate, or other character of a process becomes altered by the continued operation of extraneous forces upon it. The sounding-board which has been attuned to certain vibrations may gradually acquire a new 'set' if the standard pitch of the instrument is slightly raised or lowered. We may assume in like manner that the set of a neuron is gradually altered by the passage through it of impulses which are characterized by other modes than its own. This character of neural activity was treated in chapter iv under the name of *modification.*

The modification of the complex set of a neuron is assumed to be the basis of the new qualities observed in imagery and thought. It explains in part the variety of subjective experience. It also accounts for the specific qualities of thought and the wide gap which appears between the fundamental types of ideational experiences (imagery) and the higher types of symbolic ideation (thought). In 'imageless thought' the set of the given neuron or neurons is so completely modified that the transformed experience has lost all resemblance to its original source.

It should be emphasized that this view of neural activity is adopted only as a working hypothesis. The modal interpretation appears to meet the facts more satisfactorily than any other so far suggested. The problem remains quite open, however, pending direct evidence from physiological investigation.

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PROBLEM IV

THE VISUAL PROCESS

Principal Facts. — Like the nerve impulse, the visual process is apparently open to very precise experimental investigation. The facts are so obvious that it would seem an easy matter to explain them. The difficulty lies in the variety of phenomena presented and the apparent irreconcilability of certain facts with certain others. The visual process is a sort of Chinese puzzle, whose parts certainly can be fitted together, but which has not yet been completely solved.

The visual data (hues, shades, color-shades, and tints) depend primarily upon the rate and intensity of the physical light waves which stimulate the rods and cones of the retina. When we vary the stimuli in various ways, introduce variations of general illumination, alternate different stimuli, stimulate contiguous areas of the retina, etc., certain peculiar results are observed in the sensation. The problem is to discover a physiological process of such a nature that it will produce *all* the results actually observed. So far every theory proposed fails at one or more points. At least one piece in our Chinese puzzle is always left over.

The principal facts to be explained are given in Table XXIII. The theories proposed to account for the visual process have generally been based on certain of these facts and have found difficulty in explaining others.

Three-Color Theories. — The oldest modern theory, called the Young-Helmholtz Theory, was proposed by Thomas Young and amplified by Hermann von Helmholtz. It is based upon the three 'fundamental' colors (4).[1] Since all color hues can be produced by appropriate mixtures of a

[1] These numbers refer to the facts listed in the Table.

Table XXIII. — Visual Phenomena

A. Relations among Colors:

1. Hues at the *two ends* of spectrum (R and V)[1] are similar.
2. *Purple* is a simple visual impression, though not a spectral hue.
3. Mixture of two neighboring hues gives a simple *intermediate* hue (e.g., R+Y=O).
4. Any hue may be obtained from mixtures of *three fundamental hues*, R, G, and B.
5. There are *four distinct primal hues*, R, Y, G, and B.

B. General Relations of Colors to Grays:

6. Mixture of any hue with a certain other hue (called its *complementary*) produces gray.
7. Mixture of *all spectral hues* together produces gray.

C. Special Relations of Colors to Grays:

Gray sensation, not color, is produced

8. —— by color stimuli of *faint intensity;*
9. —— by color stimuli affecting a *small retinal area;*
10. —— by color stimuli affecting the *periphery of the retina.*
11. Certain color stimuli produce gray, not color, in *color-blind* individuals.

D. Complementary Relations of Colors and of Grays:

12. *Fatigue* leads to complementary after-effects on the same retinal area (e.g., B gives Y, Bk gives W).
13. Complementary *contrast effects* appear simultaneously on neighboring areas under certain conditions.

E. Miscellaneous Relations:

14. Absence of stimulation on a portion of the retina may yield a sensation (*Black*) on that area.
15. Under varying illumination the relative brightness of colors may vary (*Purkinje phenomenon*).

[1] In the table and following discussion the spectral colors are designated by initials: R = red, etc. Also W = white, Bk = black.

certain R, G, and B (or R, G, and V) it was assumed that the cones of the retina comprise three distinct substances, and that each cone is supplied by three nerve fibers of distinct sorts. Thus a red light-wave would stimulate the red-sensitive substance; this would excite an impulse in the red-conducting fiber and produce the sensation Red. And so for

G and B. Intermediate hues (including Y) would stimulate two of the substances. Stimulation of all three substances in equal degree produces the sensation W.

This theory was modified when research failed to reveal three distinct *substances* in the retina; and three distinct sorts of *process* were assumed instead. The Young-Helmholtz Theory with its modifications constitutes a group of *Three-Color* theories. The Three-Color theories explain facts 1 to 4 in the list. They were indeed devised especially to meet these facts. They are also based upon 7, and they readily account for 6. Peripheral gray (10) may be explained by the absence of cones in the peripheral region. Color-blindness (11) may be explained as due to some structural defect, such as absence of one of the three substances, or to conditions which destroy the basis for one of the processes. The fatigue complementary (12) is due to exhaustion of one component. The Purkinje phenomenon (15) may be explained by assuming that the three substances (or processes) follow different quantitative laws.

The remaining facts do not readily square with this type of theory. Y does not resemble R or G any more than G resembles B, or B resembles R. How then explain the primal character of Y (fact 5)? Facts 8 and 9 seem to directly contradict the theory. For when only a small area is affected by a color stimulus one would expect a *very distinct* color impression to occur, rather than gray; and when the stimulus is faint one would expect (if anything) *less* tendency to gray sensation than to the specific color. The simultaneous contrast-color effect (13) is the most troublesome fact to account for on the Three-Color basis. Helmholtz explained it by assuming that it is not a peripheral phenomenon at all; he regarded it as a cerebral phenomenon — a mental judgment. The same explanation is used to account for Black (14).

Metabolic Theories. — A distinct type of theory, based upon the antagonistic processes of anabolism and katabolism, was proposed by Ewald Hering to meet these difficulties.

Several modifications of Hering's views are generally grouped together as Antagonistic-Process or *Metabolic* theories. These theories are based primarily upon facts 5, 6, 13, 14. They assume three different pairs of metabolic processes in the retina. Each pair consists of two antagonistic[1] processes — one anabolic, the other katabolic. In the first pair the anabolic process furnishes the sensation G, the katabolic R; in the second the anabolic gives B, the katabolic Y; in the third, which is more wide-spread than either of the others, the anabolic process gives Bk, the katabolic W. Note that the R, Y, and W sensations resemble one another and are in marked contrast with G, B, and Bk; the former group are 'warm' colors, the latter 'cold.' The several processes were first attributed by Hering to three distinct substances in the retina, but inasmuch as appropriate substances were not to be found, they were later assumed to be distinct sorts of chemical action in the retina.

The Metabolic theories account especially well for the four primal colors (5) and for Black (14). They explain facts 1 to 3, mixtures (6, 7), and the fatigue complementary (12) as plausibly as the Three-Color view; they have the merit of accounting for the small-area (9) and faint-stimulus (8) phenomena, which play havoc with Three-Color theories generally. The phenomenon of peripheral gray (10) is accounted for by assuming that both the B—Y and G—R processes are lacking at the periphery, while color-blindness (11) is attributed to the entire lack of one (or both) of these processes in the retina of certain individuals. The Purkinje phenomenon (15) may be readily understood by assuming quantitative differences between the B—Y and G—R processes. An advantage of this type of theory is its explanation of simultaneous contrast (13) as a retinal process. Any given visual process in one area of the retina, it is assumed, tends to draw the requisite chemical elements from the surrounding regions, which

[1] Greenwood suggests that these be more appropriately called *opposite* processes.

serves to arouse the antagonistic process in these neighboring parts; this would also explain Bk—W contrast (13), which presents considerable difficulty to the Three-Color theories.

The Metabolic theories do not attempt to explain how all hues can be obtained from mixtures of three 'fundamental' colors (4). This is not a serious difficulty; yet one sees no reason why one primal color (Y) should be so much less fundamental than the other three. According to this type of theory the sensations B, G, and Bk are the result of anabolic processes; whereas in other receptor fields only katabolic processes give rise to nerve impulses. It is further objected that whereas in two of the pairs (Y—B, R—G) the antagonistic processes when they occur simultaneously are supposed to neutralize each other, in the third pair the simultaneous occurrence of the antagonistic processes yields Gray, a sensation which resembles one member of the pair (W). None of these objections strikes a vital blow at the Metabolic interpretation. They merely give an impression of incompleteness or lameness in the explanation.

The weightiest objection to this type of theory is the empirical fact that the members of one pair, primal R and primal G, do not actually neutralize each other as the hypothesis requires they should. The four specific colors selected as primal have been determined empirically; they are produced by certain wave lengths which yield the same quality of sensation with no variation of hue as the stimulus passes from fovea to periphery. The fact that one pair does not meet the basal condition of the theory (complete opposition) seems sufficient reason for seeking a radical revision.

Genetic Theory. — The Ladd-Franklin theory is described in chapter ix. It supposes that the visual process is a genetic growth. In the first, undifferentiated stage of the color molecule the Gray process alone exists; later the color molecule becomes differentiated so that it is capable of yielding a pair of antagonistic processes, Y and B; in a still later

stage the *Y component* is differentiated so that it furnishes two antagonistic processes, R and G; combining the two latter processes therefore produces Y, not Gray. Thus the Genetic theory meets the most serious difficulty in the Metabolic theory. It also reconciles the puzzling phenomena that there are four *primal* colors (5) and only three *fundamental* colors (4).

The most serious difficulty in this theory is its inability to account satisfactorily for the sensation Black. It also seems to assume, like the Metabolic theory, that anabolic processes yield nerve impulses and sensations.

The Genetic theory explains the facts far better than any other hypothesis so far devised. One cannot but feel, however, that the complex phenomena of visual sensation denote a more intricate physiological process than any of the current theories presuppose. We have scarcely yet begun to investigate the fine structural components and elementary chemical activities in the retina which play the chief rôle in visual stimulation. Till these are better known any hypothesis is at best only tentative.

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DIRECTIONS FOR PERFORMING THE EXERCISES

THE practical exercises given at the end of the chapters are intended to train the student in precise, critical observation of mental phenomena. They may be classed as follows:

(1) Observation of the student's own experiences;
(2) Observation of the behavior of others;
(3) Critical examination of experiences;
(4) Experiments, requiring exact performance;
(5) Miscellaneous.

(1) *Self-observation.* — It is no easy matter to observe and report one's own experiences accurately. No one can do this successfully without considerable practice. If the problem is to examine the nature of your thought of *a house,* you are likely to include not merely the essential factors of the thought experience, but various *other* thoughts and images which the word suggests.

Or again, let the problem be to report what you actually saw (perceived) after looking for ten seconds at a certain painting. Unless you have trained yourself in observing and reporting experiences, your report is almost sure to show important omissions, alterations, and actual additions of details. You describe a man in the picture as having his eyes open, when in point of fact the face is in profile or partly hidden so that you saw only one eye. Generally the more common and familiar the type of experience, the more liable we are to observe carelessly.

In the exercises which involve observations of your own perceptions, thoughts, emotions, etc., what is wanted is an *exact description of the experience* in its proper relations — not what you think it *probably* was, or *must* have been. You should caution yourself again and again to *observe carefully,* and *report with precision.* Insofar as you fail in either of

these objectives the value of the report is diminished. At the same time it should be remembered that precision in these matters can only be attained after considerable practice. Accuracy in self-observation is a matter of *psychological training*, not an ethical problem.

(2) *Observation of others.* — The same cautions apply to the second type of exercises — observation of the behavior of other individuals, including children and animals. Unless you watch carefully, you are apt to " read into " your observation many details which may have occurred but which you did not actually observe. In describing the behavior of children and animals it is safer to *stick to the observed facts* and avoid assigning motives.

(3) *Analyses.* — A third type involves not merely observation but critical examination of some personal experience. Here the problem is to select the important elements, and to indicate so far as possible the order of their importance.

This involves an additional difficulty. We are inevitably influenced by our own presuppositions and by social tradition. It requires considerable practice to get rid of these factors. You have been told that in states of anger this or that factor predominates. But *does* it, in the specific experience you are studying? The aim of this type of exercise is to train you to *do your own analyzing*, instead of depending upon what you have been taught, or upon snap judgments.

(4) *Experiments.* — In experimental work apparatus has to be constructed or prepared. It is important also to arrange the entire program with *exactness.* The details should be carefully noted, recorded, and incorporated in the report. In an experiment on learning, for instance, the duration of each trial and the lapse of time between trials should be decided upon in advance. You should note in the record the *actual* duration of work and length of intermissions, as well as the amount accomplished and the number of errors. The experiments given in the book do not call for special apparatus,

but they require more or less preparation, and in some cases involve the coöperation of a second individual.[1]

General Program. — It is suggested that one exercise be undertaken each week, preferably on a topic connected with the previous week's study. At least one exercise in each chapter deals with common, every-day experiences or with familiar material, and admits of performance at any time. Those which deal with unusual phenomena (such as hyperesthesia) may be offered as alternatives to students who have had the appropriate experiences.

The reports should be written up in such a way as to be easily understood by a "person of average intelligence." The description should proceed in consecutive order and should be expressed in clear language. Conciseness is preferable to minute detail, provided nothing essential is omitted.

The exercises should be performed regularly, week by week. If the work is bunched toward the end of the course its training value is lost. With school or college classes the rule might be made that each exercise be written up and handed in on an assigned date. It would be helpful for the instructor to discuss with students individually the first exercise of each type.

Bear in mind constantly the two-fold aim of the exercises:

(1) Accurate observation of the data of psychology and their relations.

(2) Training in scientific method and procedure.

[1] Helpful suggestions regarding procedure will be found in Titchener's "Experimental Psychology, Student's Manual"; see especially Introduction to Volume 1.

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